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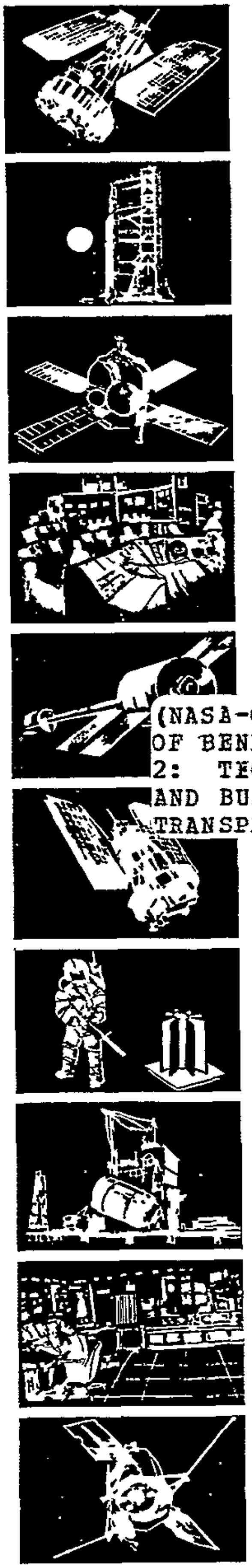

Document No. 75SDS4281

STUDY FOR IDENTIFICATION OF BENEFICIAL USES OF SPACE

(PHASE III)

FINAL REPORT

VOLUME II - TECHNICAL REPORT

BOOK 2 - DEVELOPMENT AND BUSINESS ANALYSIS OF SPACE PROCESSED TRANSPARENT OXIDES

CONTRACT NAS8-28179

NOVEMBER 30, 1975

SUBMITTED PER DPD #451,
DR #MA-04

GENERAL ELECTRIC

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Submitted Per DPD #451, DR #MA-04

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SPACE DIVISION

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PREFACE

The Final Report on Phase III of the Study for Identification of Beneficial Uses of Space (B. U. S.) is comprised of three volumes:

Volume I	Executive Summary
Volume II	Technical Report
Volume III	Appendices

Volume II is further subdivided:

Book 1 - Development and Business Analysis of Space Processed Isoenzymes

Book 2 - Development and Business Analysis of Space Processed Transparent Oxides

Book 3 - Development and Business Analysis of Space Processed Tungsten X-ray Targets

Book 4 - Development and Business Analysis of Space Processed Surface Acoustic Wave Devices

Book 5 - Study Methods and Trade Studies

General Electric's Space Division, under contract from the NASA's Marshall Space Flight Center completed Phase I of the Study in December 1972, and Phase II in December 1973. In Phase III, the Study has progressed to the Business Analysis and Planning for the commercial development and production of the four products in Phase II:

- Surface Acoustic Wave Components
- Transparent Oxides
- High Purity Tungsten X-ray Targets
- High Specificity Isoenzymes

The methodology employed in the Phase III Study and the results of that effort are reported herein.

In addition to Key Individuals from the participating User organizations who contributed specific product, process, business and planning data in each of their respective areas, the Study Manager acknowledges the outstanding financial and manufacturing analysis contributions of Mr. P. Schmitt, and the considerable contributions of the following: Mr. U. Alvarado and Mr. M. Clarke of the Study Team in analyzing and organizing the wealth of data accumulated; Mr. K. Taylor, the MSFC Contracting Officers Representative (C.O.R.) for the study, in providing key technical suggestions and direction to the overall effort as well as establishing space processing payload guidelines, Mr. G. Wouch, Dr. E. Okress, and Dr. B. Noval of General Electric's Space Sciences Laboratory, in providing supporting space processing data, and Mr. B. Klawans and Mr. F. Curran of General Electric's Systems Operation and Computations Component in programming and processing "INVEST", the interactive profitability analysis program.

As noted in the Final Reports of earlier Phases, publication of this Phase III report neither implies NASA endorsement of any specific product, process or venture identified during this phase of the Study, nor a NASA commitment to pursue any program defined as part of this Study.

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SECTION I
INTRODUCTION

This volume comprises preliminary development plans, analysis of required R & D and production resources, the costs of such resources, and, finally, the potential profitability of a commercial space processing opportunity for the production of transparent forms of certain metallic oxides. The work reported herein is a continuation of investigations into the space processing of Transparent Oxides which have been conducted in Phases I and II of NASA Study Contract NAS 8-28179 (1971-1973).

Technical support for these investigations has been provided by General Electric Space Sciences laboratory in Valley Forge, Pa., primarily by

G. Wouch, and
D. Ulrich

with consultation by

G. McLellan, of Corning Glass Works, and various members of General Electric Research and Development Center.

The baselines selected for development planning are conceptual, and were established to provide a means of assessing overall technical and economic feasibility under conditions of limited experimental space processing information and very long range market, space facility, and cost projections. These baselines can be expected to change, perhaps even drastically, as later analytical and experimental investigations continue.

I.1 BACKGROUND

The need for materials possessing new combinations of refractive index and dispersion, and extended transmission into the infrared and ultra violet regions has been noted by such organizations as the National Academy of Sciences/National Academy of Engineering.

Typically, the properties sought-for are:

Index of Refraction:	Approximately 2.0
Dispersion:	20
Thermal Stability:	Useable at temperatures up to 1000°C with stable properties to that temperature
Chemical Stability Optical Transmission Abrasion Resistance	At least as good as present silicate glasses

The oxides of aluminum, zirconium, and yttrium are recommended for initial processing. When quenched from the melt in spherules 100 - 800 µm diameter, all of these oxides have remained amorphous. Therefore, they seem like appropriate candidates for processing aimed at producing glasses in sizes large enough to be practical for components of optical systems.

These oxides have not been successfully produced in the glassy state on earth. The materials have a low viscosity when molten and devitrify readily when cooled. Levitated and melted in the clean environment of space, it is possible that the absence of crucible walls, and the elimination of contaminants that can serve as nuclei for crystal growth, would permit undercooling and, therefore, glassy alumina, zirconia, and yttria.

It is not possible to predict with any accuracy the properties of a material that has never been produced, but optical transmission in the infrared beyond 5.0 µm seems like a realistic possibility.

If glassy alumina, zirconia, and yttria prove impossible to produce in space, there is a possibility that early experiments would show that it is possible to produce polycrystalline materials of more closely controlled crystallite size than is possible on earth. If this proves to be the case, then it would be well to follow with processes designed to produce spinels, which are interesting from an optical standpoint since they are isotropic. Properties of these materials are given in Figure I-1.

Material	Density (g/cm^3)	Melt PT (^oC)	Linear Thermal Expansion (Multiply by $10^{-7}/^oC$)	Index of Refraction
Alumina	4.0	2070	70-119	1.73 (?)
Yttria	4.5	2410	81-94	1.92 2.13-2.20
Zirconia	5.2	2690	72-144	?

Figure I-1. Properties of Candidate Materials

I.2 ASSUMPTIONS

In addition to the basic Study Assumptions reviewed in Section IV of Volume I, the following key assumptions have been made in the development planning:

- The experiments and tests, defined in Phase II and updated in this Phase, will result in a successful technique for producing at least one of the metallic oxides of the type under study, with the desired properties.

- Sounding rocket, KC 135, drop tower, as required, and Shuttle/Spacelab services will be available to meet development requirements.

- In-space power requirements for transparent oxides processing (20-60 Kw peak) will be available as needed.

- The availability of an on-orbit transparent oxides processing facility, not requiring launch and recovery for each production flight was a late assumption in the Study, and is discussed in Volume I, Section IV.1.

- An initial Study Guideline (Section IV.1, Volume I) directed that our profitability analysis assume that each user bear the full cost of developing the Space Process utilized for producing his product. All four of the products under study were unattractive ventures under the combination of this assumption and derived economic data. The NASA C.O.R. suggested that this combination be noted as "Case A".

He further suggested that, since basic processes would have broader application than the individual products under study, it could likely be assumed that basic process proof-of-feasibility would be carried out under government funding. Users, therefore, would only bear those R&D costs that specifically provide prototype/pilot plant capability. The combination of this assumption and the same derived economic data as in the prior case is called "Case B". While some financial measures were very attractive in Case B, the "breakeven point" was still not favorable, and further assumptions led to "Case C". Assumptions for Case C include those of Case B, plus increasing the market share and the unit price by 50%. If the product meets established technical goals, these two assumptions should easily prove to be fact.

I.3 PRODUCT OBJECTIVES

The primary product objective is to utilize the space environment to aid in producing boules of undevitrified, or at least, new transparent polycrystaline, forms of certain metallic oxides (typically alumina, zirconia, yttria.) While there are more areas of uncertainty involved in this product than in the other products under study, micron size particles of these oxides, produced in the laboratory under limited conditions, have exhibited characteristics which tend to support this objective.

The second objective is to produce components for optical systems using space-processed oxides which are capable of achieving transmission in the infrared beyond 5.0 μ , while maintaining high temperature ($\sim 1000^{\circ}$ C) and chemical stability, as well as good structural and hardness characteristics.

I.4 PROCESS ALTERNATIVES AND BASELINE

The alternative process methods and key steps in the baseline approach selected for this Phase of Study have been derived in Phase II. These are shown in Figure I-2. Those major alternatives and decisions left unresolved in Phase II, due to lack of critical phenomenological or process data, have for the most part, been resolved by assumptions for purposes of this phase of study. It must be noted, however, that a high degree of judgement has been exercised in making the required selection.

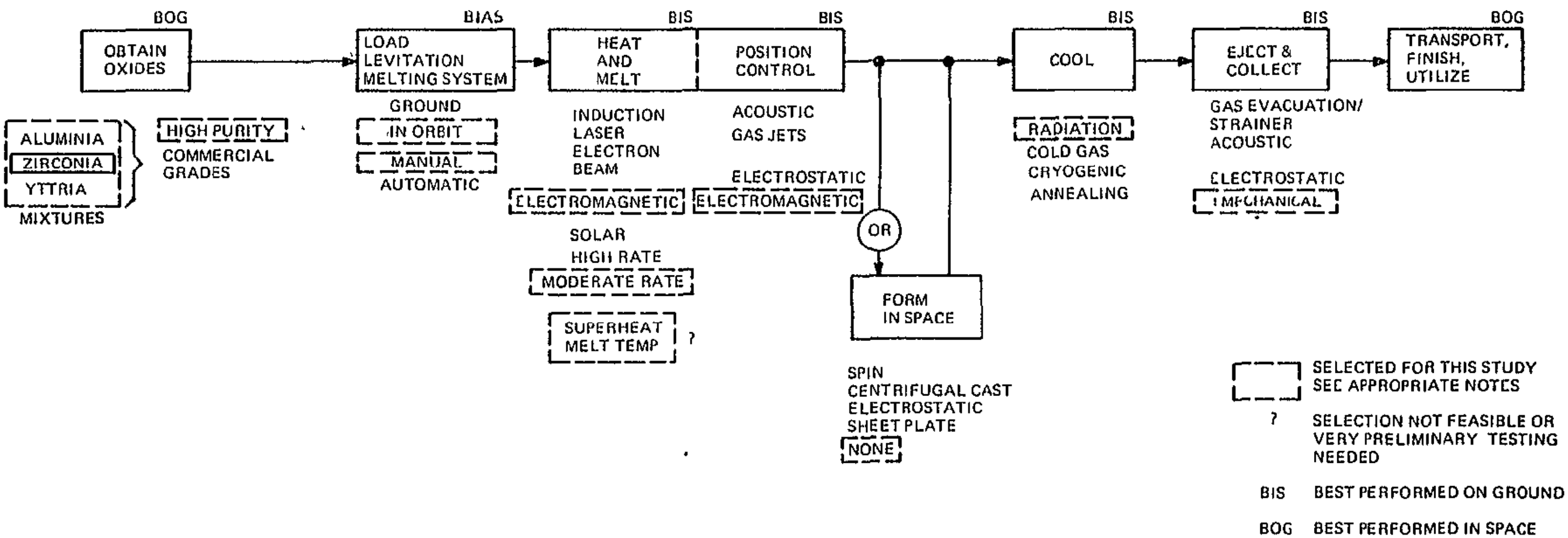


Figure I-2. Definition of Best Implementation Approach for Transparent Oxide Processing

The technical decisions and unknowns associated with this selection are given in Figure I-3.

The unknowns listed in Figure I-3 are those which form the basis for the subsequent definition of experiment and test Work Elements in the R&D portion of the Work Breakdown Structure. Current ground-based experimentation on techniques for eliminating devitrification in solidifying glass melts, supplemented by the analysis of forthcoming Sounding Rocket experiments will provide answers to some of the unknowns listed. On the other hand, the unknowns related to scale-up, effects of process on material stress, and forming during solidification require longer "zero g" duration and are likely to be the pacing item in the development of this product.

Resolution of any such unknowns through current or other future programs are not accounted for here, but will, of course, influence the future application of this Study's findings.

Baseline process data defining key requirements for the selected process are shown in Section II. 2. 5.

Decision Areas	Current Baseline Method
Choice of oxide material	Alumina, Zirconia*, Yttria
Choice of oxide purity	High purity
Location for loading levitation/melt system	In orbit
Choice of automatic or manual loading	Manual
Choice of superheat or melt temperature	• $\sim 100^{\circ}C$ superheat
Choice of high or moderate rate heating	• High (20°/sec)
Choice of heat method	RF
Choice of melt method	RF
Choice of positioning method	RF
Choice of cooling method	Radiation
Choice of forming (in space or on ground)	Ground
Choice of eject/collect method	• Mechanical
Choice of eject/collect location	In space

Unknowns

- Best Heating method. RF with pre-heat by susceptor may be replaced by laser, or hot wall furnace.
- Cooling rates to achieve supercooling prior to solidification, compatible with elimination of devitrification or with formation of polycrystalline oxides with acceptable crystal size.
- Effects of sample size on cooling rates or vice versa.
- Effects of cooling rates on induced thermal stress, and effects of those stresses on product properties.
- Performance characteristics of various heating methods (solar and arc imaging, laser, heated walls, induction/with susceptor, electromagnetic/microwave cavity, electron beam).
- Performance characteristics of various positioning methods (acoustic, gas stream, electrostatic, electromagnetic).
- Choice of available oxides and effects of impurities (type and amount)
- Types and rates of gas contaminant efflux versus temperature.
- Process development and design data for combined positioning, heating and cooling in selected approach and sequences.
- Performance and design parameters of full scale equipment.
- Loading and response of equipment during mission cycle.
- Scale-up parameters.
- Capabilities of various in-space forming methods (mechanical, gas jet, electromagnetic, centrifugal).
- Effects of various levels of vacuum and various inert gas atmospheres on contaminant efflux and level during degassing and melting.

*Zirconia Used in Typical Calculations

Figure I-3. Transparent Oxides Decisions

SECTION II

DEVELOPMENT PROGRAM

The framework upon which development tasks, schedules, costs, equipment and facility needs, etc. are constructed, is the Work Breakdown Structure (WBS). While relatively unfamiliar outside the Aerospace/Military communities, it is felt to provide sufficiently valuable insight to program planning to warrant its introduction into this commercial product study.

We have, however, deviated from the usual WBS content. The long development effort for products under study, the need for both Space and Ground Processing steps, the obvious comparisons between familiar ground processes and the "new" Space-involving process led us to establish a WBS based on process steps, rather than on equipment. Thus subsequent analyses could easily compare value added versus cost-added for any process step.

This section of the report details the WBS for the transparent oxide processing program and summarizes the Work Element Descriptions, Work Element Resource Requirements, and Resource costs. Finally, it assembles the Development Schedule.

II.1 WORK BREAKDOWN STRUCTURE

The Work Breakdown Structure against which the development and production tasks are organized is shown in Figure II-1 A&B. Figure II-1A depicts the configuration of the WBS at the top level, while II-1B delineates the detailed structure. The development effort which is documented in over 87 pages of Work Element Descriptions, Work Element Resource needs and Resource Costs, is summarized in Section II.2.

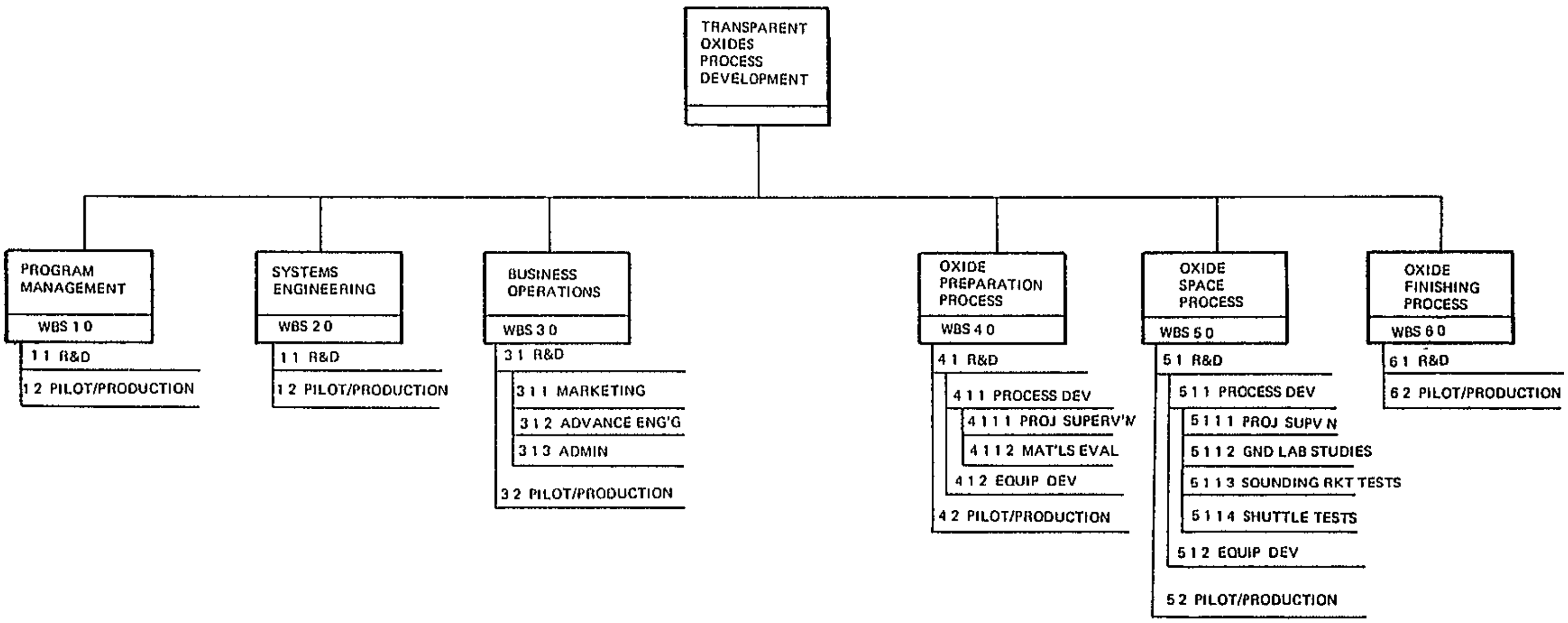


Figure II-1A. Work Breakdown Structure

- 1.0 Program Management
  - 1.1 Program Management - R&D
  - 1.2 Program Management - Pilot/Production
- 2.0 System Engineering
  - 2.1 System Engineering - R&D
  - 2.2 System Engineering - Pilot/Production
- 3.0 Business Operations
  - 3.1 Business Operations - R&D
    - 3.1.1 Marketing
    - 3.1.2 Advance Engineering
    - 3.1.3 Administration (legal, finance, etc.)
  - 3.2 Business Operations - Pilot/Production
- 4.0 Oxide Preparation Process Step
  - 4.1 Oxide Preparation Process Step (R&D)
    - 4.1.1 Process Development
      - 4.1.1.1 Project Supervision
      - 4.1.1.2 Materials Evaluation
    - 4.1.2 Equipment Development
  - 4.2 Oxide Preparation Process Step (Pilot/Production)
- 5.0 Oxide Space Process
  - 5.1 Oxide Space Process (R&D)
    - 5.1.1 Process Development
      - 5.1.1.1 Project Supervision
      - 5.1.1.2 Ground Lab Studies
        - 5.1.1.2.1 System Loading Phenomenology
        - 5.1.1.2.2 Reaction to Gas & Inert Atmospheres
        - 5.1.1.2.3 Heating & Melting
        - 5.1.1.2.4 Levitation and Melting (One-G)
        - 5.1.1.2.5 Forming Techniques (One-G)
        - 5.1.1.2.6 Correlation of Shuttle Test Data with Ground Lab Data
      - 5.1.1.3 Sounding Rocket Experiments
        - 5.1.1.3.1 Levitation & Positioning (Zero-G)
        - 5.1.1.3.2 Process Test (Zero-G)
      - 5.1.1.4 Shuttle Tests
        - 5.1.1.4.1 Process Test (Zero-G)
        - 5.1.1.4.2 Forming Test (Zero-G)
        - 5.1.1.4.3 Process Test (Zero-G)
        - 5.1.1.4.4 Prototype/Proof Test (Zero-G)
    - 5.1.2 Equipment Development
      - 5.1.2.1 Chamber/Shield/Feed/Retrival Equipment
      - 5.1.2.2 Heat & Position Equipment
      - 5.1.2.3 Power Conditioning Equipment
      - 5.1.2.4 Instrumentation & Control Equipment
      - 5.1.2.5 Vacuum & Gas Supply System Equipment
  - 5.2 Oxide Space Process - Pilot/Production
- 6.0 Oxide Finishing Process Step
  - 6.1 Oxide Finishing Process Step - R&D
  - 6.2 Oxide Finishing Process Step - Pilot/Production

Figure II-1B. Transparent Oxide Development Work Breakdown Structure

The technical and business assessment of the in-space Transparent Oxide processing opportunity requires that all elements of work required, from raw materials to finished product be examined, costed, and assessed. The main process steps provide a suitable framework for collecting tasks and costs over that sequence of events, and this approach tends to assure that no major business costs are overlooked. Six major process steps are defined for Transparent Oxide processing:

Oxide Preparation	(WBS 4.0)
Oxide Space Processing	(WBS 5.0)
Oxide Finishing	(WBS 6.0)

To the above elements, work elements for integrating and planning the development and pilot/production program are added as follows:

Program Management	(WBS 1.0)
System Engineering	(WBS 2.0)
Business Operations	(WBS 3.0)

Each major WBS element is divided into R&D and Pilot/Production phases, with the R&D phase ending at completion of a prototype capability. Work and cost summaries can thus be obtained either for a process step or for a particular phase. The ability to summarize a process step facilities comparison of the cost of a process relative to others, assessment of alternatives (e.g., ground cutting - versus space forming - of elements), the examination of value added in each process step and examination of the option to sell as a product, the output of a particular process step.

Within each process, work is subdivided as to whether it is Process Development (requirements, system design, subsystem and system tests) or Equipment Development (component design and test based on process requirements). Hardware breakdown as used in aerospace Work Breakdown Structure occurs at lower levels of the Equipment Development branch.

II.2 WORK ELEMENTS (WORK TO BE DONE)

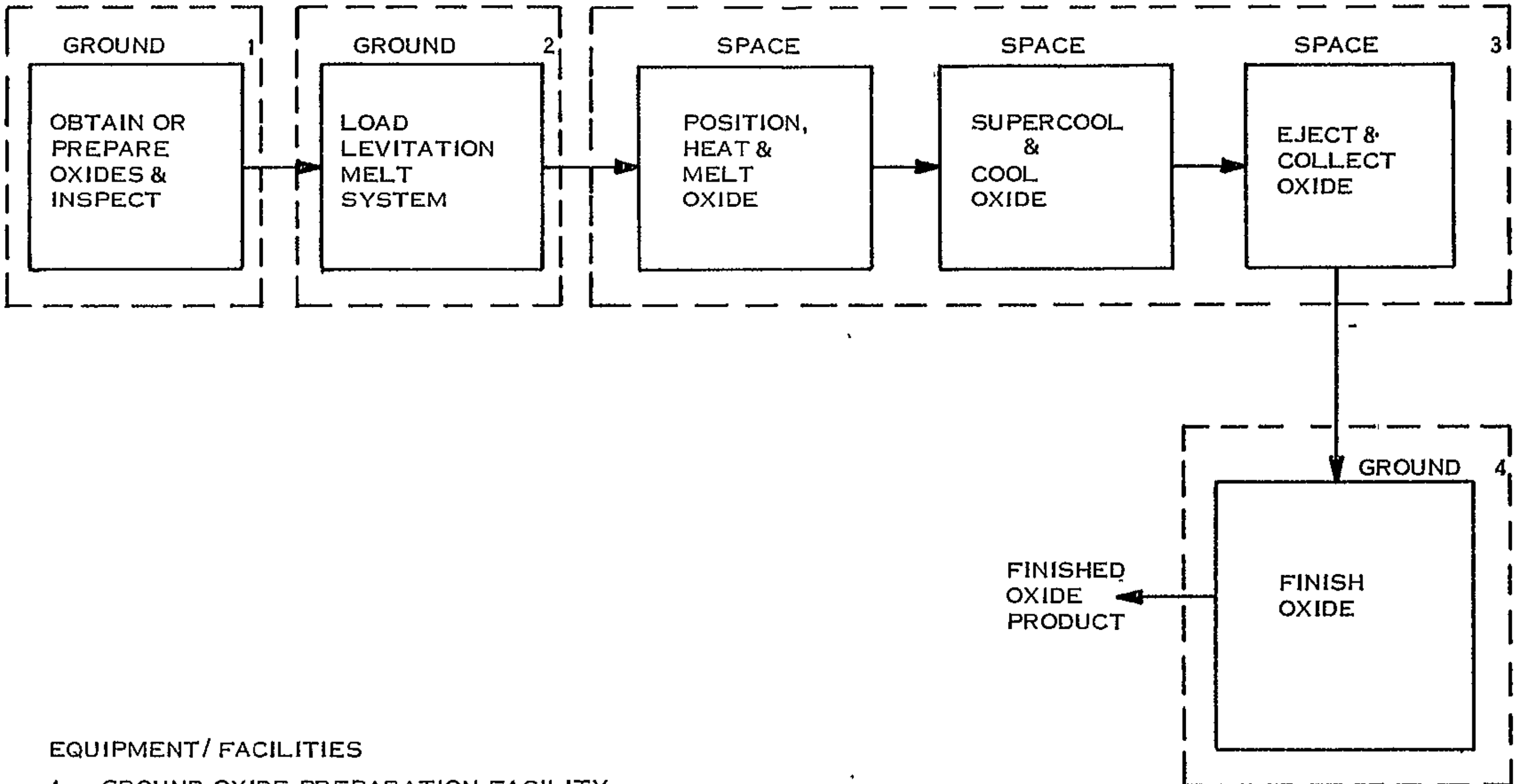
The development of a ground/space process for fabrication of transparent oxide optical elements capable of improved transmissivity, such as that pictured in Figure II-2, can be summarized into the following work elements:

1.0 Program Management
2.0 System Engineering
3.0 Business Operations
4.0 Oxide Preparation Process Step (ground)
5.0 Oxide Space Process Step (space)
6.0 Oxide Finishing Process Step (ground)

These elements apply to both the development (R&D) phase and production phase. The R&D effort is largely concentrated in element 5.0, Oxide Space Process Step, and this development plan accordingly emphasizes that area of work. A description of the work to be done in each work element is given in the following paragraphs. The development program includes a series of major experiments and tests as shown in Figure II-3a. The Sounding Rocket and Shuttle tests are summarized in Figure II-3b.

II.2.1 PROGRAM MANAGEMENT (WBS 1.0)

Program Management in the R&D phase will include the definition of development tasks and schedules, arranging for and controlling the resources needed and maintaining a management liaison with the parties involved. These parties will include the oxide research laboratory, oxide product manufacturer, oxide space systems contractor, NASA centers and NASA contractors. While each development area (process step) will include project supervision of that work, Program Management will provide for the overall management and integration of all aspects of the program. Reports, presentations, special documents and plans are also included in Program Management. When the production phase is instituted, Program Management will



EQUIPMENT/ FACILITIES

1. GROUND OXIDE PREPARATION FACILITY
2. GROUND LEVITATION SYSTEM LOADING FACILITY
3. SPACE POSITION, HEAT, MELT, COOL, EJECT, COLLECT FACILITY
4. GROUND OXIDE FINISHING FACILITY

Figure II-2. Transparent Oxide Processing Ground/Space Process Steps & Facilities

			WBS
Process Phenomenology	1.	Oxide Properties, Reactivities vs. Levitation Process Ground Lab	5.1.1.2.1
	2.	Oxide Reactivities to Processing Atmoshperes, Ground Lab	5.1.1.2.2
Process Step Evaluation	3.	Heating and Melting Studies, Initial Studies, Ground Lab	5.1.1.2.3
	4.	Levitation and Positioning Initial Studies, Ground Lab	5.1.1.2.4
	5.	Evaluation of Forming Techniques, Initial Studies, Ground Lab	5.1.1.2.5
Verification of "Zero G" Equipment	6.	Design Test of Process Equipment for "Zero G" operation, Ground Lab	5.1.1.2.6
	7.	Initial Test of "Zero g" positioning, Sounding Rocket	5.1.1.3.1
	8.	Selected Process Evaluation (1G), Ground Lab	5.1.1.3.2
	9.	Selected Process Evaluation ("Zero g"), Shuttle	5.1.1.4.1
	10.	Product Forming Techniques, Shuttle	5.1.1.4.2
Pilot/ Prototype	11.	Design Test of Process Equipment, Shuttle	5.1.1.4.3
	12.	Prototype Proof Test, Shuttle	5.1.1.4.4

Figure II-3A. Transparent Oxides Test Series

WBS No	Test	Expmt. No	Power Req'd (kw)	Expmt. Weight (kg)	Expmt Vol. (M^3)	Flt Date (yr)	Total Expmt. Duration	Flt. Crew Support Req'd	Flight Vehicle	Data Transmission Req'mts	Data Processing Req'mts	Energy Req'd (KWH)
5.1.1 3 1	Positioning Methods	1A	1	100	0 2	1976	5-10 min	no	S/R-1	TBD	TBD	0.5
		1A	1	100	0 2	1977	5-10 min.	no	S/R-2	TBD	TBD	0.5
		1A	1	100	0 2	1978	5-10 min.	no	S/R-3	TBD	TBD	0 5
5 1 1 3 2	Process Evaluation	5A	1	200	0 2	1979	5-10 min	no	S/R-1	TBD	TBD	0.5
		5A	1	200	0 2	1980	5-10 min.	no	S/R-5	TBD	TBD	0 5
5 1 1.1 1	Forming	6A	1-7	550	1	1981	8-120 hrs.	yes	Shuttle SL-1	none	none	100
5 1 1 1.2	Equipment Evaluation	7A	1-7	550	1	1982	8-120 hrs.	yes	Shuttle SL-2	none	none	100
		7A	4-7	550	1	1983	8-120 hrs	yes	Shuttle SL-3	none	none	100
5 1 1.4 3	Prototype Evaluation	8	20-15	800	1 5	1984	120 hrs	yes	Shuttle SL-4	none	none	400
5 1 1 4 4	Prototype Proof	8	20-15	800	1.5	1985	120 hrs	yes	Shuttle SL-5	none	none	400

Figure II-3B. Transparent Oxide Processing Flight Test Requirements for R&D

be reduced to routine activities mostly handled by administration and production control functions of the business. Also, some project engineering services will be required to handle shuttle services and interfaces.

II.2.2 SYSTEM ENGINEERING (WBS 2.0)

In the R&D phase, System Engineering will be required to establish requirements and specifications for the overall ground-space-ground process, as portrayed in Figure II-4 to be designed, and to integrate or conduct tests of overall processes. As development tests eliminate the present unknowns and technology gaps, System Engineering will convert these findings to a specific prototype system design (ground-space) and ultimately to a pilot/production facility design. In commercial terms, this is a combined plant engineering and product engineering activity, with the added dimensions of space vehicle/payload interfacing and orbital operations requirements. The output of the R&D System Engineering effort will be overall process and materials specifications and process equipment design requirements. In the production phase, System Engineering reduces to following engineering and technical (e.g. Shuttle) interface support.

II.2.3 BUSINESS OPERATIONS (WBS 3.0) (WBS 3.1)

Business Operations in the R&D phase will be concerned with business preparations in anticipation of a successful development effort and initiation of production. Business planning must be done continuously as a basis for investment decisions as R&D results are obtained. Three areas of Business Operations are described as follows:

<u>Marketing (WBS 3.1.1, 3.2.1)</u>

The development program initiation is necessarily based on very early estimates of business viability and financial returns. During the R&D activity, Marketing must continuously analyze the potential market, market share, anticipated orders, product offerings, gross margins, product costs, profits, etc. in order to confirm or modify

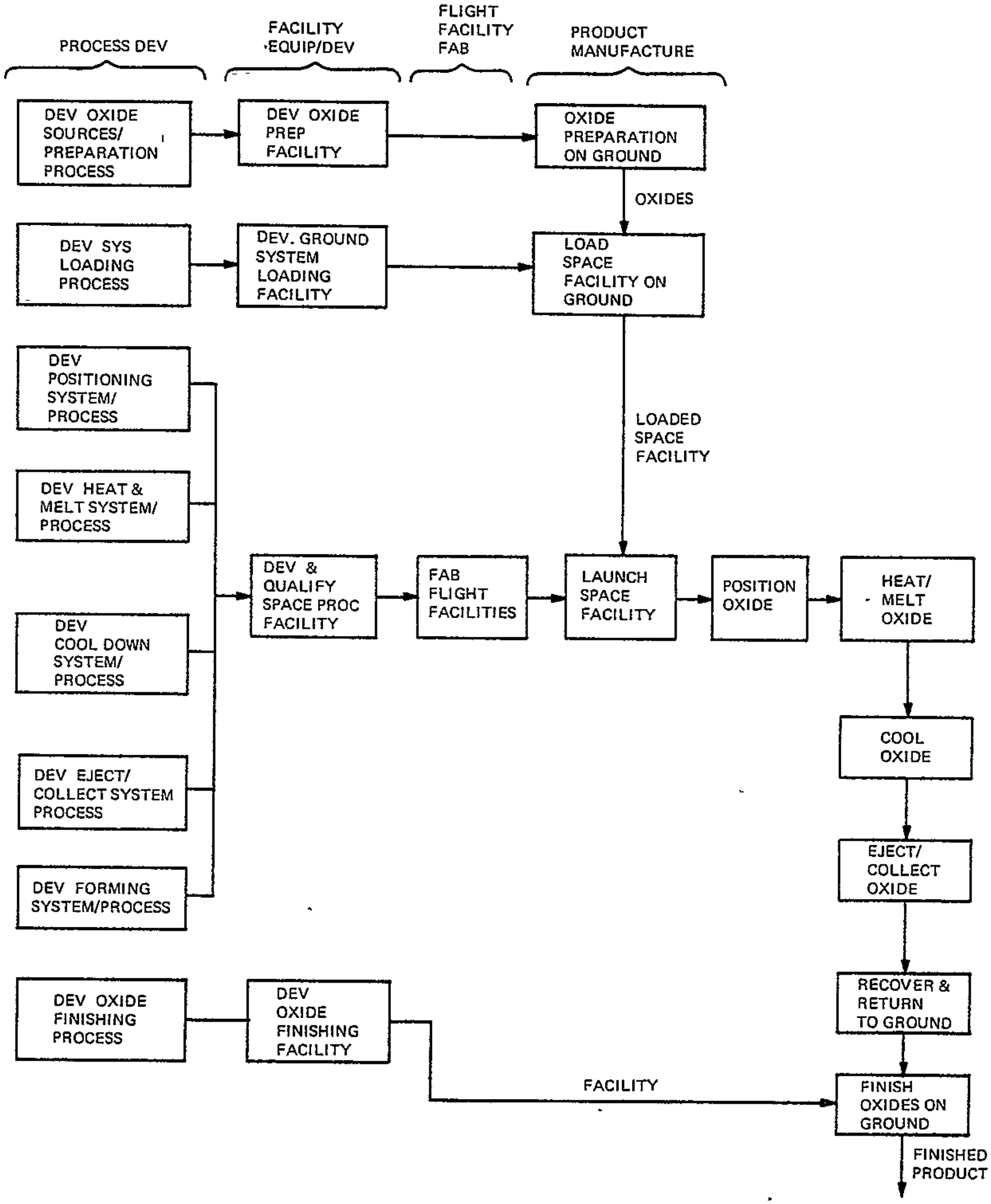


Figure II-4. Transparent Oxide Production-Development & Mission Profile earlier plans. As the time of pilot production approaches, Marketing will prepare sales literature, preliminary catalog data, and price data as the basis for customer contacts. The product distribution system will be designed and an appropriate sales organization will be initiated. Demonstrations of product characteristics and performance will be conducted using samples from early tests, and prototype/pilot runs to convince customers of product advantages and to establish a preliminary seller/purchaser understanding. Advance orders will be solicited as early as possible in the R&D phase to reduce the risk associated with a commitment to build production facilities. When the production phase begins, Marketing will conduct routine order processing, cataloging, product service, product planning, and sales engineering activities as well as future market/business planning.

Advanced Engineering (WBS 3.1.2, 3.2.2)

Advanced Engineering will be relatively quiescent during the R&D phases since the R&D System Engineering and Process Step R&D tasks will be accomplishing that function. A limited amount of second generation technical investigation will be done to explore opportunities which lie beyond the scope of the R&D effort. These findings may have an effect on the direction of the R&D effort. When the production phase begins, Advanced Engineering work will increase, to develop improvements in the pilot production design and to introduce new processes, facilities, and products as suggested by Marketing plans.

Financial, Legal & Relations Support (WBS 3.1.3, 3.2.3)

In the R&D phase, the Finance, Legal, & Relations functions will participate with Marketing in the preparation and critique of business plans, and recommending of steps to be taken by management to prepare for production. The timing and amount of investment will be critical, with pressures to move quickly to establish a market position, and concurrent pressure to postpone action, to reduce financial risk. Relations will be concerned with staffing of R&D positions and planning for production staff. Legal will address the contract/subcontract terms anticipated for production, and the insurance/indemnity/warranty provisions that are planned to be used. This work will include establishing of the terms for using NASA shuttle services, and the associated manufacturer/NASA liabilities.

II.2.4 OXIDE PREPARATION PROCESS STEP (WBS 4.0)

Establishment of such characteristics as initial purity, grain morphology, microstructure, thermo-physical, electrical, optical, etc. properties will be necessary to select the candidate materials for space processing of metal oxides such as yttria, zirconia, and alumina to produce these new glasses. Because of the critical knowledge gaps that must be filled in order to determine the feasibility of producing new and unique glasses of utility and high value through containerless processing in the weightless environment of space, the results of the space processing investigation (WBS 5.0) must interface with the development of the oxide preparation step. The effort will establish the initial parameters such as purity, type, shape, size, grain morphology, microstructure, thermophysical, electrical, and optical properties of the specimen to be processed in space. A series of tests, such as are represented in the typical Work Element Description, Resource Requirement, and Resource Cost Formats in Figure II-5 will be required to characterize candidate materials and determine, via ground tests, which candidate materials should be selected.

The equipment and process required must be defined for each candidate metal oxide material, as well as the handling, transport, and storage requirements prior to space processing. In the production phase, a facility for the preparation of one or more metal oxides will be required, with an appropriate throughput.

II.2.5 OXIDE SPACE PROCESS STEP (WBS 5.0)

Critical knowledge gaps exist, which must be filled in order to produce these new and unique glasses. Some of these gaps are listed below:

1. The level of conditions (convection, presence of contaminents, vibration, etc.) conducive to formation of amorphous or improved crystalite phases in such metal oxides as zirconia, alumina, and yttria.

TASK DESCRIPTION		
TASK TITLE Evaluation of Candidate Sample Materials		
WBS NO. 4.1.1.2	PREPARED BY G. Wouch/D. Ulrich	DATE 8/74

1. REQUIRED OUTPUT:

Compositions and a specimen preparation method (and possibly a supplier) that will yield samples likely to form glasses when melted in levitated condition. Pre and post process characterization of samples by well-established materials characterization techniques.

2. REQUIRED INPUT:

Samples of alumina, yttria and zirconia rods; masses to 12, 16 and 17 grams respectively. Compositions may include glass-forming combinations. Rods are 1 cm diameter and 3-4 cm in length. Select high purity materials which have been produced by several suppliers using different methods of preparation.

3. DESCRIPTION OF EFFORT:

Activity 1 - Pre-characterization of starting samples.

Activity 2 - Heat, melt, homogenize and cool specimens in controlled inert gas, oxygen or vacuum environments.

Activity 3 - Post characterization of processed samples to determine quantity, quality and location of glass formed.

4. PERFORMANCE PERIOD 9-12 months: (1) Pre-characterization - 1 week/specimen, (2) Sample processing - 2-3 hrs/specimen, (3) Post-characterization - 1 wk/spec. - 27 spec. per comp. - 81 spec. for 3 compositions

PERFORMANCE RESPONSIBILITY:	APPROVAL
Corning	

NOTE CONTINUE NUMBERED ITEMS ON SEPARATE SHEET AS REQUIRED

Figure II-5. Task Description

TASK RESOURCE REQUIREMENTS

TASK TITLE		
Evaluation of Candidate Sample Materials		
WBS NO. 4.1.1.2	PREPARED BY G. Wouch/Ulrich	DATE 8/74

1. PURCHASED MATERIALS: (INCLUDE ASSUMPTIONS)

Alumina, yttria and zirconia rods. May require purchase of rods containing binary or ternary compositions of alumina, yttria and zirconia with content of glass-forming oxides. Rods are 1 cm diameter and 3 cm length. Rods precut and machined for surface finish based on heating systems selected. Certification of: (1) quality and characteristics of presintered powders as provided by raw material supplier; and (2) quality of sintered rods as provided by supplier of finished specimens.

2. PURCHASED SERVICES (INCLUDE ASSUMPTIONS)

Materials characterization (assume that user has material characterization facilities and expertise.

3. EQUIPMENT: (INCLUDE ASSUMPTIONS)

High frequency RF generator up to 15M Hz; furnace to preheat zirconia to 2000°C; leviation coil; pyrometer; gas sampling analyzer.

4. FACILITIES: (INCLUDE ASSUMPTIONS)

Power, water, high voltage cable.

APPROVAL:

NOTE. CONTINUE NUMBERED ITEMS ON SEPARATE SHEET AS REQUIRED.

Figure II-5. Resource Requirements

WORK ELEMENT COSTS

WORK ELEMENT NO. 4.1.1.2

WORK ELEMENT TITLE Evaluation of Candidate Sample Materials

1 ACT. NO.	2 ACTIVITY	3 LABOR COST	4 PURCHASED MATERIALS COST	5 SERVICES COST	6 EQUIPMENT COST	7 FACILITIES COST	8 TOTAL COST
1	Pre-characterization of Samples		$10,000	$97,000			$107,000
2	Heat, Melt and Cool	$6,000			$26,000-$36,000		$32,000-$42,000
3	Postcharacterization of Samples			$97,000			$97,000
	TOTALS	$6,000	$10,000	$194,000	$26,000-$36,000		$236,000 $246,000

Figure II-5. Work Element Costs

2. Best (most efficient, least disturbing) methods of heating the charge such as electromagnetic, thermal imaging, laser, hot wall furnace, etc.
3. Best (most efficient, most compatible) method for preheating the specimen before injection into the processing chamber and final heating.
4. Heating and cooling rates.
5. The method of positioning such as electromagnetic or acoustic.
6. The gas environment such as vacuum, inert gas, or active gas.
7. Vaporization rates in various atmospheres.
8. Process steps and duration.
9. Method of charge injection and recovery of finished product.
10. Permissible rate of feeding and throughput.
11. Design and operational requirements for hazards such as high temperature, and for waste products such as oxide deposits.

The R&D effort will be directed at obtaining resolution of the knowledge gaps in order to specify design, fabricate, and test a prototype space facility with a unit charge capacity of 0.003 to 0.006 kilograms (experimental) and 1 to 3 kilograms (pilot/production scale), with associated positioning, feed, recovery, processing chamber, heating, quenching (if appropriate), sensor, and control components.

Key areas of concern are:

1. Process Feasibility
2. High Power Requirements
3. Heat Rejection
4. EMI
5. Safety

Ground based levitation, heating, degassing where required, melting and supercooling studies will be performed to evaluate these key areas and to evalute process steps and equipment for space processing. These will provide the basic data for Sounding

Rocket experiments, listed in Figure II-6, directed at glass formation through supercooling, using small specimens. A representative Work Element Description, its Resource Requirements, and Cost of Resources for a Sounding Rocket experiment is given in Figure II-7. Some work in drop towers or KC-35 airplane flights may prove useful. Success in these small-scale experiments will warrant and provide base-line data for scale-up experiments on shuttle flights, defined in the Work Element Description, Resource Requirements, and Resource Cost format in Figure II-8. The objective is to achieve a 1 to 3 kilogram unit charge, depending on the available power. A prototype proof demonstration will be conducted on a shuttle flight (or flights) to confirm all processes and product specifications. Successful prototype operation at an acceptable charge size and throughput, and a confirmed product demand will form the basis for implementation of routine production at the pilot plant level or greater capacity. Baseline process requirements for both a Shuttle experiment and production are given in Figure II-9.

A conceptual configuration for the full scale Transparent Oxides processing facility is shown in Figure II-10. The configuration is basically the same modular facility used to process the Tungsten product in this Study, with the Electron Beam Gun and its supporting equipment removed, and a susceptor for preheating the oxides accounted for.

In conjunction with the Transparent Oxides product efforts, we reviewed over 40 different potentially applicable equipments for these development programs. As a result, we list in Figure II-11, a summary of our estimate as to new developments required for the Transparent Oxides program.

The R&D effort will not address the raw power source except to establish a suitable power conditioning interface with a power source provided by NASA. Later production designs may provide for an integrated high power heat source, such as a solar collector/solar furnace.

FACILITY	EXPERIMENTS AND VERIFICATION TESTS	OBJECTIVES	EXPERIMENT AND TEST REQUIREMENTS (SUMMARY)
GROUND LAB	1 Purity analysis melting x ray examination alumina, zirconia yttria from various sources produced by various processes Small samples high purity In hard vacuum and inert gas To select initial materials most likely to produce desired glasses via space processing	Evaluation of specific oxides	Standard ground lab with controlled atmosphere furnace (~3000°C) specimens of high purity alumina zirconia yttria from various sources trace impurity analysis equipment x ray crystalography vacuum system inert gas system 1 2 day per specimen Manual
	2 Heating, melting selected oxides to determine effects of vacuum level and/or inert gas atmosphere need for contaminant removal Also degassing reactions phase changes	Definition of processing conditions	Standard ground lab with furnace(s) accommodating carbon arc imaging heater or laser and electron beam gun, vacuum and inert gas Selected specimens of alumina zirconia yttria Mass spectrometer radiation pyrometer vacuum sys tem and inert gas system Materials characterization lab 4 hours per specimen run 2 days per specimen for characterization Manual
	3 Heating experiments with solar arc laser heated chamber electromagnetic electron beam equipment on selected oxides To establish time temperature response melting rate effects on impurities uni formity of heating other effects, and select most efficient compatible heating method Investigate cooling effects	Material heating methods and responses	Standard lab as above plus accommodation for solar imaging hot chamber and electromagnetic heating Other requirements as above plus melt measuring apparatus and cooling equipment 8 hours per specimen run 2 days for characterization
	4 Experiments on positioning capability of acoustic gas stream, electrostatic forces vs solid alumina zirconia yttria (Microwave forces as backup) To establish maximum controllable specimen mass position velocity acceleration levels and to select most effective compatible control method	Material positioning methods and responses	Standard lab with levitation apparatus Various weights of specimens Accom modation for acoustic gas stream electrostatic microwave positioning devices Position sensing velocity and acceleration measuring equipment, photography Automated positioning remainder manual
	5 Test of combined positioning, heating melting cooling under selected conditions to make prelimi nary process evaluation accrue development and design data	Process feasibility	Standard lab as in 2 3 4 above under conditions and with apparatus selected as result of 2 3 4 Provision for modification of conditions, apparatus to optimize performance Automated with provision for manual override 7 0 hours per run
	6 Experiments on achievable shape variety accuracy of electrostatic, other techniques	Forming techniques (future possibility)	Standard lab and equipment optimized from 5 Accommodating apparatus for several forming techniques (e g gas jets electromagnetic) including centri fugal casting with and without mold), gas dynamic, etc Manual 1 2 hours per run
ENGINEERING LAB	Development engineering qualification tests	Equipment design data	Standard lab with shake tables vacuum and thermal chambers centrifuge etc Testing to confirm adequacy of design for shuttle sortie loads and conditions, for compatibility among processing equipments, for estimating/confirming performance of equipments, etc. Instrumentation for loading, environment response Recording of data Photography
DROP TOWER	Experiments on positioning capability of acoustic gas stream electrostatic forces vs solid alumina zirconia, yttria (Microwave forces as backup) To establish maximum controllable specimen mass position velocity, acceleration levels and to select most effective compatible control method	Material positioning methods and responses	Drop Tower selected positioning method(s) from above Largest specimen weights compatible with test package Integrated package of positioning device, instrumentation, power supply, data recording telemetry Automated duration of runs 3 10 seconds Telemetry or recording of data recovery of test package
KC 135	Experiments on positioning capability of acoustic gas stream electrostatic forces vs solid alumina	Material positioning methods and responses	KC 135 selected positioning method(s) from above Largest specimen weights compatible with test package Integrated package of positioning device
SOUNDING ROCKET	Experiments on positioning capability of acoustic, gas stream, electrostatic forces vs solid alumina, zirconia, yttria (Microwave forces as backup). To establish maximum controllable specimen mass, position, velocity, acceleration levels, and to select most effective, compatible control method.	Material positioning methods and responses	Sounding Rocket positioning method(s) from above Largest specimen weights compatible with test package. Integrated package of positioning device, instrumentation, power supply, data recording, telemetry Auto mated duration of runs 6 10 minutes Telemetry or recording of data, recovery of test package
	Test of combined positioning, heating, melting, cooling under selected conditions to make pre liminary process evaluation, accrue development and design data	Process feasibility	Sounding Rocket with test package based on design data and conditions derived from ground lab tests. Test package to include apparatus for positioning, heating, melting, cooling per preprogrammed profile and sequence, power supply, instrumentation, data recording Telemetry of data, recovery of test package 6-10 minutes Automated

Figure II-6. Experiments to Verify Selected Approach for Transparent Oxide Processing

TASK DESCRIPTION

TASK TITLE Initial Studies - Levitation and Positioning (Zero-G)

WBS NO. 5.1.1.3.1	PREPARED BY G. Wouch/D. Ulrich	DATE 7/23/74

1. REQUIRED OUTPUT:

Evaluation and selection of position control technique for containerless processing. Evaluation of performance characteristics of position control systems. The effect of the positioning medium on the candidate materials will be analyzed.

2. REQUIRED INPUT:

Same as 5.1.1.2.4. Results of 5.1.1.2.4. Knowledge of sounding rocket capabilities and space processing packaging development.

3 DESCRIPTION OF EFFORT:

- Develop experiment packages for applicable levitation techniques for drop tower and sounding rocket experiments.
- Sounding rocket experiments to evaluate positioning and position control of molten oxide specimens. Evaluate efficiency, positioning ability, heating and positioning coupling, position control, rate of control, energy usage.
- Post characterization.

4 PERFORMANCE PERIOD 1 year plus number of sounding rocket flights allotted for experiments on this task.

PERFORMANCE RESPONSIBILITY:	APPROVAL:

NOTE. CONTINUE NUMBERED ITEMS ON SEPARATE SHEET AS REQUIRED

BUS-1

Figure II-7. Task Description

TASK RESOURCE REQUIREMENTS		
TASK TITLE Initial Studies - Levitation and Positioning		
WBS NO. 5.1.1.3.1	PREPARED BY G. Wouch/ Ulrich	DATE 8/74

1. PURCHASED MATERIALS: (INCLUDE ASSUMPTIONS)

Oxide specimens (4.1.1.2)
Parts (for experiment package)

2. PURCHASED SERVICES: (INCLUDE ASSUMPTIONS)

Materials Characterization (per 5.1.1.2.4)
Pre-launch and launch service
Data acquisition, recording and transmission service by dedicated rocket
Specimen retrieval and shipment for examination
Space qualification of experiment package (vibration, acceleration, etc.)

3. EQUIPMENT: (INCLUDE ASSUMPTIONS)

Space qualified, spaceborne mass spectrometer (like Mars Lander's)
Space qualified, spaceborne two color pyrometer
Space qualified, specially designed H.F. RF generator (to 15 mHz)
Preheating oven
Levitation coils
Chamber for packaging coils or sonic positioning
Vacuum system for controlled gas injection system
Special handling and retrieval system
Quenching system (to be designed)

or sonic position unit

4. FACILITIES (INCLUDE ASSUMPTIONS)

Launch
Sounding Rocket (Black Brant?)
Data Management
Package Retrieval
Facilities for fabrication of Space Qualified Experiment Package
Facilities for Space Qualification Test

	APPROVAL.

NOTE CONTINUE NUMBERED ITEMS ON SEPARATE SHEET AS REQUIRED.

Figure II-7. Task Resource Requirements

WORK ELEMENT COSTS							
WORK ELEMENT NO. 5.1.1.3.1	WORK ELEMENT TITLE Initial Studies-Levitation and Positioning						
1 ACT. NO.	2 ACTIVITY	3 LABOR COST	4 PURCHASED MATERIALS COST	5 SERVICES COST	6 EQUIPMENT COST	7 FACILITIES COST	8 TOTAL COST
1	Experiment Package Design Fabrication and Cost	130K to 260K	10K to 20K		100K	25K	265K to 405K
2	Sounding Rocket Launch and Test Services (3 flights)			141K		Provided by NASA	141K
3	Sounding Rocket Assemblies (less Experiment Payloads)						
	Flight SR-1		234K				234K
	Flight SR-2		78K				78K
	Flight SR-3		78K				78K
	TOTALS	130K - 260K	400K - 410K	141K	100K	25K	796K - 936K

Figure II-7. Work Element Costs

TASK DESCRIPTION

TASK TITLE
Selected Process Evaluation (Zero-G)

WBS NO.	PREPARED BY	DATE
5.1.1.4.1	G. Wouch	7/23/74

1. REQUIRED OUTPUT:

Provide initial Zero "G" evaluation of selected process, to obtain process development data and refine hardware design.

2. REQUIRED INPUT:

Results of Tasks 4.1.1.2, 5.1.1.2. Familiarity with shuttle experiment package, spaceborne equipment, etc.

3. DESCRIPTION OF EFFORT:

- Experiment package development and testing, pre-flight preparation.
- Pre-launch processing.
- Launch
- Demonstrate Zero-G heating, melting, supercooling, cooling, during flight with position control and gas-temperature-time profile monitoring. Possible quench at end of weightless flight.
- Post-characterization of recovered specimens. Glass forming potential evaluation.

4. PERFORMANCE PERIOD: Six mohths to 1 year + number of shuttle flights allotted for this task. 1981

PERFORMANCE RESPONSIBILITY:	APPROVAL:
Corning/GE/NASA	Corning/GE/NASA

NOTE CONTINUE NUMBERED ITEMS ON SEPARATE SHEET AS REQUIRED

BUS-1

Figure II-8. Task Description

TASK RESOURCE REQUIREMENTS		
TASK TITLE Selected Process Evaluation (Zero-g)		
WBS NO. 5.1.1.4.1	PREPARED BY G. Wouch/D. Ulrich	DATE 8/74

1. PURCHASED MATERIALS: (INCLUDE ASSUMPTIONS)

Oxide specimens (prepared as per 4.1.1.2)
Parts (for experiment package)

2. PURCHASED SERVICES: (INCLUDE ASSUMPTIONS)

Materials Characterization (per 4.1.1.2)
Pre-launch and launch service
Data acquisition, recording and transmission service on space shuttle
Specimen retrieval and shipment for examination
Space qualification of experiment package (vibration, acceleration, etc.)

3. EQUIPMENT: (INCLUDE ASSUMPTIONS)

Space qualified, spaceborne mass spectrometer (like Mars Lander's)
Space qualified, spaceborne two color pyrometer
Space qualified, specially designed H.F. RF generator (to 15 MHz)
Preheating oven
Levitation coils or sonic position unit
Chamber for packaging coils or sonic positioning
Vacuum system or controlled gas injection system
Specimen handling and retrieval system
Quenching system (to be designed)

4. FACILITIES: (INCLUDE ASSUMPTIONS)

Launch
Space shuttle
Data management
Facilities for fabrication of space qualified experiment package
Facilities for space qualification tests

	APPROVAL.

NOTE: CONTINUE NUMBERED ITEMS ON SEPARATE SHEET AS REQUIRED.

Figure II-8. Task Resource Requirements

WORK ELEMENT COSTS

WORK ELEMENT NO. 5.1.1.4.1 WORK ELEMENT TITLE Selected Process Evaluation

1 ACT. NO.	2 ACTIVITY	3 LABOR COST	4 PURCHASED MATERIALS COST	5 SERVICES COST	6 EQUIPMENT COST	7 FACILITIES COST	8 TOTAL COST
1	Experiment Package and Development and Preparation	130K - 260K	10K - 20K		100K	25K	265K - 405K
2	Prelaunch Processing						
3	Launch			419K (NASA)			419K
4	Zero-G Flight						
5	Post-flight Characterization			100K			100K
	TOTALS	130K - 260K	10K - 20K	519K	100K	25K	784K - 924K

Figure II-8. Work Element Costs

Item	Experiment	Production
Raw Material	Zirconia, Yttria, Alumina	Same
Charge Size (diameter	1 cm dia. sphere	8 cm dia. sphere
Charge Size (weight)	3-6 grams	1-3 Kg
Preheat Temperature	$2000^{o}C$	Same
Insertion Method	Mechanical	Same
Heating Rate - High	$10\text{-}100^{o}C/sec$	Same
Heating Rate - Low	$5\text{-}10^{o}C/sec$	Same
Heat Dwell Temperature	$2000\text{-}3000^{o}C$	Same
Environment During Heat	Inert Gas/(O_2)$10^5 N/M^2$	Same
Stirring Required	Yes	Same
Maximum Temperature	$2000\text{-}3000^{o}C$	Same
Cooling Rate - Medium	$\sim 100^{o}C/sec$	Same
Cooling Rate - Low	$0.1\text{-}10^{o}C/sec$ (Controlled)	Same
Cooling Method	Radiation	Same
Heating Power	2-5 kw	25-60 kw
Product Recovery	Mechanical	Same
Time to Dwell	1-2 minutes	1-10 minutes
Time at Dwell (molten)	2-4 minutes	1-5 minutes
Time to Cool to Recovery Temperature	2-4 minutes	10-100 minutes
Total Process Time	5-10 minutes	12-115 minutes
Oxide Density	5 grams/cm^3	

Figure II-9. Transparent Metal Oxide Process Baseline

Item	Development Required?	Quantity Required			
		Initial Ground	Prototype (Space)	Pilot (Space)	Production (Space)
Furnace Chamber	Yes	1	1	1	2
Chamber Oven Temperature Sensor & Cutoff	No	1	1	1	2
Positioning System	Yes	1	1	1	2
Specimen Insertion & Retrieval System	Yes	1	1	1	2
RF Coil Cooling Unit	Yes	1	1	1	2
Susceptor Preheat & Cooling Unit	Yes	1	1	1	2
RF Power Supply & Generator	Yes	1	1	1	2
Vacuum Pump & Power Supply	No	1	1	1	2
Temperature Measurement & Control	Yes	1	1	1	2
Optical Pyrometer	(optics)	1	1	1	2
Vacuum/Pressure Measurement & Control	No	1	1	1	2
Residual Gas Measurement	Yes	1	1	1	2
Cooling Controls	No	1	1	1	2
Gas (Inert, O_2) Supply & Controls	No	1	1	1	2
Gas Evacuation System	No	1	1	1	2

Figure II-11. Development Equipment List for Transparent Oxides Processing

It is assumed that the experimental space processing facility will be installed in a "long module" (6M long, 23M^3 volume), and that the Spacelab will provide all required support from its standard support subsystems except for power requirements, which will require a Power Module/Kit to satisfy excess power needs.

Accommodation in the Spacelab requires accounting for certain special requirements involved in processing Transparent Oxides. Typical such requirements are listed in Figure II-12.

II. 2. 6 OXIDE FINISHING PROCESS STEP (WBS 6.0)

The basic oxide product as received from the space processing facility will be a sphere shape of, say, 8 cm diameter. The objective will be to cut useful lenses, prisms and windows from this sphere for high-value applications and with minimum waste. As the products to be obtained are defined, the processes to be used (to obtain the size, shape, finish, coating, etc.) will be established, probably using conventional methods. There will be an interaction between the product requirements (size, shape) and the metal oxide charge size established for the space processing facility. Also, the possibility of partial forming of the oxide shape in space to reduce waste must be determined.

II. 3 DEVELOPMENT SCHEDULE

The major activities required for Transparent Oxide process development and their phasing are as follows:

Analysis and Planning	1974-75
Levitation Melting on Earth	1975-76
Levitation Melting and Cooling-Drop Tower & KC-135 Aircraft	1975-76
Sounding Rockets Experiments	1976-80
Shuttle/Spacelab Tests	1981-84
Orbital Pilot Plant (Operational Demonstration)	1985
Orbital Production (Operational Capability)	1985 & beyond

Requirement		Equipment or Operations Need
Safety		
• Temperature	–	3000°C superheated zirconia requires enclosure, fire proofing, possible emergency quench.
• Electrical Power	–	RF Power Supply is high power, requires grounding, fusing, potting of connectors.
• RF	–	EMI requires shielding, filters in power line.
• Optical	–	Molten Zirconia brighiness requires eye shields.
Wastes		
• Gases	–	Provision to remove Inert Gas, O_2
• Solids	–	Accommodate or remove deposits of metal oxides.
• Heat	–	Thermal Control for up to 3×10^6 joules (experiment) 30×10^6 joules (production)

Figure II-12. Special Requirements for Processing Transparent Oxides

The detailed development schedule is shown in Figure II-13.

Laboratory experiments in the 1975-1980 period are primarily aimed at acquiring basic information on fundamental processing steps; pre-heating, levitation, laser or radiant (as possible supplement to electromagnetic) heating, and combined processing effects.

Drop Tower tests could provide useful data as early as 1975, while Zero "G" aircraft and Sounding Rocket tests in 1975 and 1976 are programmed for key positioning system tests. Sounding Rocket tests form the backbone of testing the major process steps (positioning, heating, melting, and supercooling) in 1976 to 1980.

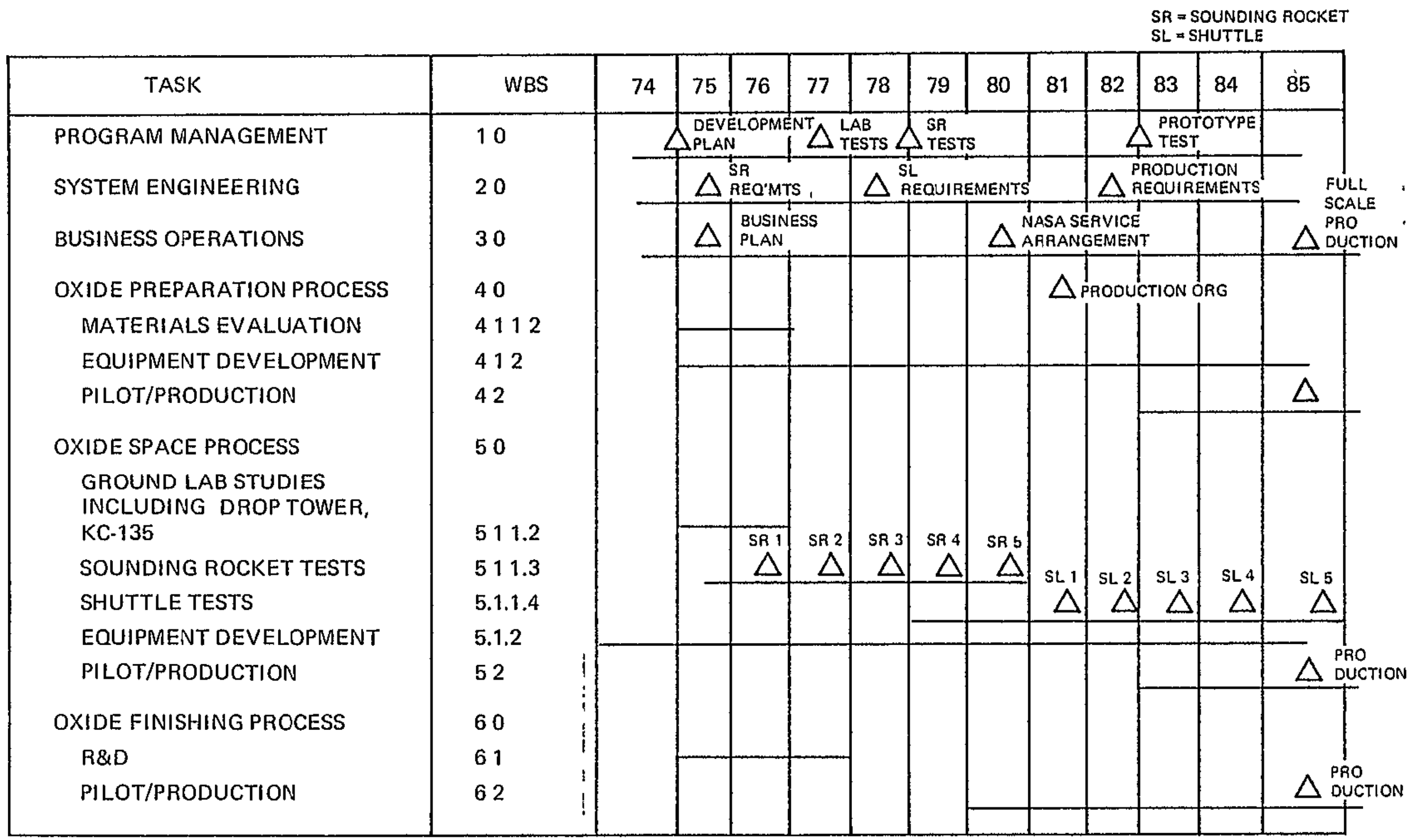


Figure II-13. Transparent Oxide Product/Process Development Schedule

SECTION III

RESOURCES PLANNING

As in the preceding section, which extracted the program activities, their key milestones and timing, from the documented Work Elements in order to provide Development Planning data, we also analyzed the Resource Requirements and Resource Costs documents to extract the Resource Planning data.

Based on these requirements and costs, we have delineated the planned allocation of development costs for the Transparent Oxide program under study. For programmatic purposes, these allocations have been assembled under several combinations of categories: types of resource, WBS elements, timing, and for both Case A and Case B.

A summary of the estimated costs for Case A, broken down by major resource category, is shown in Figure III-1 for each major WBS Element and in Figure III-2 for lower level WBS Elements. The $17.9 million total program cost includes the cost of NASA service charges for a Sounding Rocket, and Shuttle flights in the R&D phase.

A time-phased statement of those same costs for Case A is given in Figure III-3, with Figure III-4, broken down to the lower levels of WBS Elements.

Case B costs for R&D (wherein the User does not bear the proof-of-process-feasibility costs) are shown in Figures III-5 and 6. User costs in this case are estimated at $9.3 million.

It is important to recognize that costs are, in some cases, only measures of resources such as personnel with key skills, facilities, special equipment, etc. A tabulation of such resources by WBS element is shown on Figure III-7.

WBS	Task	Labor Cost	Purch. Mat'ls. Cost	Services Cost	Equip. Cost	Facilities Cost	Total Cost	Time Period
1.1	Program Management	-	-	1626K	-	-	1626K	75 - 85
2.1	System Engineering	-	-	1478K	-	-	1478K	75 - 85
3.1	Business Operations	-	-	-	-	-	-	-
4.1	Oxide Prep. Process	271K	23K	229K	81K	20K	624K	75 - 82
5.1	Oxide Space Process	4456K	864K	5594K	1555K	1185K	13654K	75 - 85
6.1	Oxide Finishing Process	146K	30K	100K	175K	50K	501K	75 - 82
	TOTALS	4873K	917K	9027K	1811K	1255K	17883K	

Figure III-1. Transparent Oxides R&D Program Summary (Case A)
(By Task & Cost Element)

WBS	Task	Labor Cost	Purch. Mat'ls. Cost	Services Cost	Equip. Cost	Facilities Cost	Total Cost	Time Period
1.1	Program Management	-	-	1626K	-	-	1626K	75 - 85
2.1	System Engineering	-	-	1478K	-	-	1478K	75 - 85
3.1	Business Operations	-	-	-	-	-	-	-
4.1	Oxide Preparation Process	271K	23K	229K	81K	20K	624K	75 - 82
4.1.1	Process Development	63K	10K	194K	36K	-	303K	75 - 82
4.1.1.1	Project Supervision	57K	-	-	-	-	57K	75 - 82
4.1.1.2	Evaluation of Candidate Mat'ls.	6K	10K	194K	36K	-	246K	75 - 76
4.1.2	Equipment Development	208K	13K	35K	45K	20K	321K	75 - 82
5.1	Oxide Space Process	4456K	864K	5594K	1555K	1185K	13654K	75 - 85
5.1.1	Process Development	3456K	764K	4594K	1170K	1135K	1119K	75 - 85
5.1.1.1	Project Supervision	1011K	-	-	-	-	1011K	75 - 85
5.1.1.2	Ground Lab Studies	1381K	135K	634K	250K	50K	2450K	75 - 83
5.1.1.2.1	Basic Phenomenology	58K	-	20K	-	-	78K	75 - 76
5.1.1.2.2	Init. Studies - Reaction to Gasses, etc.	8K	10K	108K	50K	-	176K	75 - 76
5.1.1.2.3	Init. Heating & Melting Studies	18K	10K	200K	50K	-	278K	75 - 76
5.1.1.2.4	Init. Studies - Levitation & Positioning	31K	5K	-	-	-	36K	75 - 76
5.1.1.2.5	Eval. of Forming Techniques	18K	10K	216K	50K	-	294K	75 - 76
5.1.1.2.6	Proc. Equip. Des. Test & Qual.	1248K	100K	90K	100K	50K	1588K	81 - 83
5.1.1.3	Sounding Rocket Experiments	344K	569K	275K	120K	35K	1343K	76 - 77
5.1.1.3.1	Init. Studies - Levit. & Position (0-G)	260K	410K	141K	100K	25K	936K	76 - 77
5.1.1.3.2	Selected Process Eval, (1-G)	84K	159K	134K	20K	10K	407K	77
5.1.1.4	Shuttle Experiments	720K	60K	3685K	800K	1050K	6315K	79 - 85
5.1.1.4.1	Selected Process Eval. (0-G)	260K	20K	519K	100K	25K	924K	79 - 81
5.1.1.4.2	Eval. of Forming Techniques (0-G)	260K	20K	938K	100K	25K	1343K	80 - 83
5.1.1.4.3	Process Equip. Design Test & Qual.	100K	10K	1114K	100K	500K	1824K	79 - 84
5.1.1.4.4	Prototype/Proof Test (0-G)	100K	10K	1114K	500K	500K	2224K	81 - 85
5.1.2	Equipment Development	1000K	100K	1000K	385K	50K	2535K	75 - 82
6.1	Oxide Finishing Process	146K	30K	100K	175K	50K	501K	75 - 82
6.1.1	Process Development	146K	30K	100K	175K	50K	501K	75 - 82
6.1.1.1	Project Supervision	46K	-	-	-	-	46K	75 - 82
6.1.1.2	Ground Lab Tests	100K	30K	100K	175K	50K	455K	75 - 82
	TOTALS	4873K	917K	9027K	1811K	1255K	17883K	

Figure III-2. Transparent Oxides R&D Program (Incl. Space (Charges) (Case A) (By Task & Cost Element) (Upper Value Used Where Range Was Estimated)

WBS	Task	Total	75	76	77	78	79	80	81	82	83	84	85
1.1	Program Management	1620K	16K	190K	151K	58K	66K	100K	268K	219K	182K	190K	153K
2.1	System Engineering	1178K	12K	172K	110K	52K	60K	91K	243K	200K	165K	173K	140K
3.1	Business Operations	-	-	-	-	-	-	-	-	-	-	-	-
4.1	Oxide Preparation Process	621K	88K	228K	41K	44K	66K	66K	44K	44K	-	-	-
5.1	Oxide Space Process	13654K	306K	1457K	1297K	425K	425K	735K	2438K	1958K	1666K	1661K	1286K
6.1	Oxide Finishing Process	501K	22K	39K	55K	55K	110K	110K	55K	55K	-	-	-
	TOTALS	17883K	504K	2086K	1690K	631K	727K	1102K	3048K	2176K	2013K	2024K	1579K

Figure III-3. Transparent Oxides R&D Program Summary (Case A) (By Year)

WBS	Task	Total	75	76	77	78	79	80	81	82	83	84	85
1.1	Program Management	1626K	16K	190K	151K	58K	66K	100K	268K	219K	182K	190K	153K
2.1	System Engineering	1178K	12K	172K	110K	52K	60K	91K	213K	200K	165K	173K	140K
3.1	Business Operations	-	-	-	-	-	-	-	-	-	-	-	-
4.1	Oxide Preparation Process	621K	88K	228K	11K	11K	66K	66K	41K	44K	-	-	-
4.1.1	Process Development	303K	88K	187K	1K	1K	6K	6K	1K	4K	-	-	-
4.1.1.1	Project Supervision	57K	8K	21K	1K	4K	6K	6K	4K	4K	-	-	-
4.1.1.2	Evaluation of Candidate Mat'ls	246K	80K	166K	-	-	-	-	-	-	-	-	-
4.1.2	Equipment Development	321K	-	11K	40K	10K	60K	60K	40K	40K	-	-	-
5.1	Oxide Space Process	13651K	306K	1457K	1297K	125K	425K	735K	2438K	1958K	1666K	1661K	1286K
5.1.1	Process Development	11119K	271K	1157K	997K	25K	25K	335K	2038K	1658K	1666K	1661K	1286K
5.1.1.1	Project Supervision	1011K	25K	105K	90K	25K	25K	30K	156K	139K	147K	147K	122K
5.1.1.2	Ground Lab Studies	2150K	216K	616K	-	-	-	-	588K	500K	500K	-	-
5.1.1.2.1	Basic Phenomenology	78K	30K	18K	-	-	-	-	-	-	-	-	-
5.1.1.2.2	Init Studies - Reaction to Gasses, etc	176K	10K	136K	-	-	-	-	-	-	-	-	-
5.1.1.2.3	Init Heating & Melting Studies	278K	70K	208K	-	-	-	-	-	-	-	-	-
5.1.1.2.4	Init Studies - Levitation & Positioning	36K	16K	20K	-	-	-	-	-	-	-	-	-
5.1.1.2.5	Eval. of Forming Techniques	294K	90K	201K	-	-	-	-	-	-	-	-	-
5.1.1.2.6	Proc. Equip. Des Test & Qual.	1588K	-	-	-	-	-	-	588K	500K	500K	-	-
5.1.1.3	Sounding Rocket Experiments	1313K	-	136K	907K	-	-	-	-	-	-	-	-
5.1.1.3.1	Init. Studies - Levit & Position (0-G)	936K	-	436K	500K	-	-	-	-	-	-	-	-
5.1.1.3.2	Selected Process Eval. (1-G)	107K	-	-	107 K	-	-	-	-	-	-	-	-
5.1.1.4	Shuttle Experiments	6315K	-	-	-	-	-	305K	1291K	1019K	1019K	1514K	1164K
5.1.1.4.1	Selected Process Eval (0-G)	924K	-	-	-	-	-	305K	619K	-	-	-	-
5.1.1.4.2	Eval of Forming Techniques (0-G)	1313K	-	-	-	-	-	-	305K	519K	519K	-	-
5.1.1.4.3	Process Equip. Des Test & Qual.	1821K	-	-	-	-	-	-	210K	200K	200K	1214K	-
5.1.1.4.4	Prototype/Proof Test (0-G)	2224K	-	-	-	-	-	-	160K	300K	300K	300K	1164K
5.1.2	Equipment Development	2535K	35K	300K	300K	400K	100K	100K	400K	300K	-	-	-
6.1	Oxide Finishing Process	501K	22K	39K	55K	55K	110K	110K	55K	55K	-	-	-
6.1.1	Process Development	501K	22K	39K	55K	55K	110K	110K	55K	55K	-	-	-
6.1.1.1	Project Supervision	16K	2K	4K	5K	5K	10K	10K	5K	5K			
6.1.1.2	Ground Lab Tests	155K	20K	35K	50K	50K	100K	100K	50K	50K	-	-	-
	TOTALS	17883K	504K	2086K	1690K	631K	727K	1102K	3048K	2476K	2013K	2024K	1579K

Figure III-4. Transparent Oxides R&D Program (Incl. Space Charges) (Case A) (By Task & Year)

WBS	Task	Total	75	76	77	78	79	80	81	82	83	84	85
1.1	Program Management	818K					66K	100K	136K	136K	75K	182K	153K
2.1	System Engineering	771K					60K	91K	124K	124K	66K	166K	140K
3.1	Business Operations	-											
4.1	Oxide Prep Process	220K					66K	66K	44K	44K			
5.1	Oxide Space Process	7163K					425K	430K	1137K	1180K	1050K	1655K	1286K
6.1	Oxide Finishing Process	330K					110K	110K	55K	55K			
	TOTALS	9332K	-	-	-	-	727K	797K	1496K	1539K	1191K	2003K	1579K

Figure III-5. Transparent Oxides R&D Program Summary (Case B)

WBS	Task	Total	75	76	77	78	79	80	81	82	83	84	85
1.1	Program Management	818K	-	-	-	-	66K	100K	136K	136K	75K	182K	153K
2.1	System Engineering	771K	-	-	-	-	60K	91K	121K	121K	66K	166K	140K
3.1	Business Operations	-	-	-	-	-	-	-	-	-	-	-	-
4.1	Oxide Preparation Process	220K	-	-	-	-	66K	66K	14K	44K	-	-	-
4.1.1	Process Development	20K	-	-	-	-	6K	6K	1K	4K	-	-	-
4.1.1.1	Project Supervision	20K	-	-	-	-	6K	6K	4K	4K	-	-	-
4.1.1.2	Evaluation of Candidate Mat'ls	-	-	-	-	-	-	-	-	-	-	-	-
4.1.2	Equipment Development	200K	-	-	-	-	60K	60K	40K	40K	-	-	-
5.1	Oxide Space Process	7163K	-	-	-	-	125K	130K	1137K	1180K	1050K	1655K	1286K
5.1.1	Process Development	5663K	-	-	-	-	25K	30K	737K	880K	1050K	1655K	1286K
5.1.1.1	Project Supervision	515K	-	-	-	-	25K	30K	67K	80K	50K	141K	122K
5.1.1.2	Ground Lab Studies	1100K	-	-	-	-	-	-	300K	300K	500K	-	-
5.1.1.2.1	Basic Phenomenology	-	-	-	-	-	-	-	-	-	-	-	-
5.1.1.2.2	Init. Studies - Reaction to Gasses, etc.	-	-	-	-	-	-	-	-	-	-	-	-
5.1.1.2.3	Init. Heating & Melting Studies	-	-	-	-	-	-	-	-	-	-	-	-
5.1.1.2.4	Init. Studies - Levit & Positioning	-	-	-	-	-	-	-	-	-	-	-	-
5.1.1.2.5	Eval. of Forming Techniques	-	-	-	-	-	-	-	-	-	-	-	-
5.1.1.2.6	Process Equip Des. Test & Qual.	1100K	-	-	-	-	-	-	300K	300K	500K	-	-
5.1.1.3	Sounding Rocket Experiments	-	-	-	-	-	-	-	-	-	-	-	-
5.1.1.3.1	Init. Studies - Levit & Posit. (0-G)	-	-	-	-	-	-	-	-	-	-	-	-
5.1.1.3.2	Selected Process Eval (1-G)	-	-	-	-	-	-	-	-	-	-	-	-
5.1.1.4	Shuttle Experiments	4018K	-	-	-	-	-	-	370K	500K	500K	1514K	1164K
5.1.1.4.1	Selected Process Eval (0-G)	-	-	-	-	-	-	-	-	-	-	-	-
5.1.1.4.2	Eval. of Forming Techniques (0-G)	-	-	-	-	-	-	-	-	-	-	-	-
5.1.1.4.3	Process Equip. Des Test & Qual.	1821K	-	-	-	-	-	-	210K	200K	200K	1214K	-
5.1.1.4.4	Prototype/Proof Test (0-G)	2221K	-	-	-	-	-	-	160K	300K	300K	300K	1164K
5.1.2	Equipment Development	1500K	-	-	-	-	400K	400K	400K	300K	-	-	-
6.1	Oxide Finishing Process	330K	-	-	-	-	110K	110K	55K	55K	-	-	-
6.1.1	Process Development	330K	-	-	-	-	110K	110K	55K	55K	-	-	-
6.1.1.1	Project Supervision	30K	-	-	-	-	10K	10K	5K	5K	-	-	-
6.1.1.2	Ground Lab Studies	300K	-	-	-	-	100K	100K	50K	50K	-	-	-
	TOTALS	9332K	-	-	-	-	727K	797K	1496K	1539K	1191K	2003K	1579K

Figure III-6. Transparent Oxides User R&D Program (Case B)
(NASA Demonstrates Process Feasibility)

WBS	Task	Period (Yrs)	Special Skills	Materials	Services	Equipment	Facilities
1 1	Program Management	75 82	Conventional	N/A	Conventional	N/A	Conventional
2 1	System Engineering	75 82	Conventional	N/A	Conventional	N/A	Conventional
3 1	Business Operations	75 82	Conventional	N/A	Market surveys, catalog/sales literature	N/A	Conventional
4 1	Oxide Preparation Process	75 82					
4 1 1	Process Development	75 82	Oxide process engineer Oxide process technician	High purity alumina, yttria, zirconia rods	Pre process and post process characterization facilities and expertise	Pre heater, high freq RF generator, mixer & cooler, Inert gas, O_2 & vacuum environment	Conventional with power, water & high voltage cable
4 1 2	Equipment Development	75 82	Oxide process eng /tech	Alumina, yttria, zirconia rods	Materials characterization facilities and expertise	High freq RF generator preheat furnace, levitation coil pyrometer, gas analyzer	Conventional with power, water & high voltage cable
5 1	Oxide Space Process						
5 1 1	Process Development						
5 1 1 2	Ground Lab Studies	75 83	Oxide process eng/tech Test eng/tech of flight equipment	Precut and certified oxide pieces of process dimensions	Process design engineering Pilot plant and field eng g Materials characterization facilities and expertise	Std development lab equip shake tables thermal/vacuum chambers, centrifuge anechoic chamber, control systems instrumentation, photography data recording, and processing Bench installation of experiment. Various heating methods including lasers and electron beam Various melt forming devices Free-suspension processing system, X ray crystallography equipment	Conventional to simulated sortie lab Temps to 3000°F vacuum to 10^{-3} N/M^2. Physico-chemical property determination facilities
5 1 1 3	Sounding Rocket Exp	76-85	Oxide process eng/tech Space package tech	Alumina, yttria, zirconia samples	Sounding rocket or equiv zero-g flight services such as KC 135 or drop tower tests Materials characterization Definition of initial oxide space processes based on ground experiments	Levitation and positioning equipment. Heat, melt, cool/quench equipment. Process instrumentation, recovery package vacuum/gas unit Space qualified mass spectrometer, two meter pyrometer, hi freq RF generator	Conventional lab space, computer Fabrication facilities of space qual, experiment package & qual testing.
5 1 1 4	Shuttle Experiments	79 85	Oxide process eng/tech Orbiter payload spec		Materials characterization, computer NASA interfaces T/M control photography, TV, mounting, power etc	Test instrumentation, photographic and data recording Nominal power and thermal control support, communications displays and controls Space qualified mass spectrometer, two color pyrometer hi freq RF generator Pre heater lev coils, vacuum/gas unit handling/quench syst	NASA orbiter space, power heat rejection, interfaces Launch data management, package retrieval, space package fab and qual test
5 1 2	Equipment Development	75 82	Oxide process eng	Oxide specimens Equipment component parts	Quality control reliability/environment testing Human engineering Safety engineering	Prototype components, test equip (network analyzers etc.) test equip (vacuum vibration, etc)	Conventional plant space, power, light
6 1	Oxide Finishing Process						
6 1 1	Process Development						
6 1 1 2	Ground Lab Studies	75-82	Engineer/designer of gem finishing equip Test specialists (lens, filters)	Transparent amorphous oxide material produced in space	Materials characterization computer, optical component design and evaluation (lens windows etc)	Gem slicer, grinders/polishers thermal shaping/treatment, optical bench testing.	Conventional plant space, power, light

Figure III-7. Transparent Oxides Resource Needs Summary

SECTION IV

CASH FLOW ANALYSIS

The data inputs and parameter values used in the Case A, (User bears full R&D costs), cash flow analysis are shown in Figure IV-1. The financial forecast for this case for the period 1975 - 1992 is presented in Figures IV-2A and 2B. A total market demand of 15,000 units is assumed for all years and all cases analyzed. The unit price of $830 is used for all years in Cases A and B based on present-day high quality optical component costs.

In Case B, Figure IV-3, the user-funded research and development program to establish a production capability after demonstration of process feasibility by NASA is estimated at about $9.3 million. The detailed cash flow of Case B is shown in Figure IV-4.

Finally, for Case C we have explored some of the potential "what if's" that could be conceived as alternative scenarios. As shown in Figures IV-5 and IV-6, we have increased the market share to 50% from the 33% of earlier cases, and increased the unit price by 50% to $1245. Such changes are not outlandish. If the product achieves its full potential, Users will be able to acquire a unique capability for laboratory and specialized process applications, which may open the door to their new markets.

During the Study, various sets of assumptions in terms of throughput and approach were tried in establishing the baseline process which produce a target-segment at an acceptable unit price.

Financial analysis was based on the estimation of the following 6 items over the period 1975 - 1992.

Total Market - world demand for very high quality transparent (to IR and UV optical devices of a nominal volume of 20 cm^3.

Market Share - percent of the total market to be satisfied by the producer, based on an estimated constant share of 33% (Case A and B) and 50% (Case C) over the forecast period.

Unit Price - based on a unit price of $830 (related to the value of gallium arsenide) for Cases A and B, and elevated to $1245 per unit in Case C. The Case C price is a very high value which tests the venture for the situation where the transparent oxide optical device demonstrates a performance which is far superior to any existing devices.

Unit Manufacturing Cost - based on an itemization of the process costs to produce transparent oxide optical devices, including space and ground processing, space service charges, and final device cutting and polishing, but excluding packaging and mounting into an optical assembly.

Research and Development Cost - based on an estimate of the ground lab, sounding rocket and space Shuttle/Spacelab experiments required to achieve a prototype process capability, including the oxide preparation, space levitation and melt, and ground finishing processes.

Annual Plant and Equipment - based on the added equipment and modifications to existing plant required. A ten-year straight-line depreciation was used for purposes of analysis.

A simplified financial forecast routine was then used to determine the following business venture performance measures.

Percent Return on Investment (ROI) - this is calculated as the annual net profit (after taxes and before payment of dividends) divided by net annual investment. The significance of the return on investment measure is that it indicates the yield to the business after all costs are deducted. It can be compared on an annual basis to the return which might be obtained from alternate investment of the same funds, including the option of putting the money in a bank savings account. The baseline (Case B) ROI obtained is 17% (1992), which is an acceptable indicator, disregarding the uncertainty associated with this venture. Case C, with a higher unit price and greater market share, gives an ROI of 61% (1992), which is improbably high, but suggestive of the possibilities for good business performance, given the proper business framework.

Percent Net Income To Sales (NI/S) - this is calculated as net profit (after taxes and before payment of dividends) divided by annual sales. The significance of the net income to sales percent is that it indicates the yield relative to the amount of business (sales) being conducted, for comparison with what yield that type of business normally expects to achieve. The NI/S figure obtained for Case B is 13.2% which compares well with the industry average of 7.2% (1973). The Case C NI/S is 27.4% (1992), an improbably high value, while the Case A NI/S is 2.4% (1992), an unacceptably low value.

Cumulative Cash Flow - this is the summation of the annual amounts of money which must be put into (or can be taken out of) the business over the forecast period. Annual cash flows are determined as the annual net income after taxes less the annual net change in investment. The summation of the annual cash flows over time gives the cumulative cash flow. In general, the sooner that a business can generate positive cash flow (excess cash), the more attractive the venture. In the years when annual cash flow is positive, the business is generating more cash than is needed to operate the business. At the time when cumulative cash flow turns positive, the business will have paid back all of the money put into the business up to that time (breakeven point).

The cumulative cash flow for Case B turns positive at a point which is well beyond the end of the forecast period (1992), and like Case A has a breakeven period of greater than 20 years, a totally unacceptable performance. The Case C cumulative cash flow turns positive in 1987, with a breakeven period of 9 years, which is on the fringe of acceptability, for ventures with otherwise good indicators.

Present value - Present value is a measure of the worth today of funds expected to be paid out or received in the future, based on a chosen discount rate. The present value of the business is calculated by discounting the annual cash flows at a rate of 10%. The net annual investment in the last year of the forecast period, which can be taken as a measure of the liquidation value of the business, was included in the calculation. The present value indicated by Case B is (negative) \$2.9, a poor indicator while the present value of Case C is (positive) \$3.1 million, a good indicator. The significance of the present value measure is that, at zero present value, a business man is indifferent (theoretically) as to whether he puts his money in the bank at interest (at the assumed discount rate) or into the business (disregarding business risk). For a positive present value, he would rather put his money into the business.

Constants were established for calculation of costs other than those inputted, as shown in Figures IV-1, -3, and -5. Space charges based on the BUS Phase III model were included in the R&D and production costs.

Changes in assumptions could be made to increase the attractiveness of this conceptual venture, such as the following:

- increase unit price (Case C shows this effect)
- decrease unit manufacturing cost
- increase market size
- increase market share

INPUTS:	75	76	77	78	79	80	81	82	83	84
TOTAL MARKET (UNITS)	0.	0.	0.	0.	0.	0.	0.	15000.	15000.	15000.
MARKET SHARE (PCT)	0.	0.	0.	0.	0.	0.	0.	3.	10.	33.
UNIT PRICE	0.	0.	0.	0.	0.	0.	0.	830.	830.	830.
UNIT MANUFACTURING COST	.00	.00	.00	.00	.00	.00	.00	351.00	351.00	351.00
R AND D EXPENSE	504000.	2086000.	1690000.	634000.	727000.	1102000.	3048000.	2476000.	2013000.	2024000.
ANNUAL PLANT AND EQUIP.	0.	0.	0.	0.	0.	0.	2200000.	0.	500000.	0.

INPUTS:	85	86	87	88	89	90	91	92	93	94
TOTAL MARKET (UNITS)	15000.	15000.	15000.	15000.	15000.	15000.	15000.	15000.	0.	0.
MARKET SHARE (PCT)	33.	33.	33.	33.	33.	33.	33.	33.	0.	0.
UNIT PRICE	830.	830.	830.	830.	830.	830.	830.	830.	0.	0.
UNIT MANUFACTURING COST	351.00	351.00	351.00	351.00	351.00	351.00	351.00	351.00	.00	.00
R AND D EXPENSE	1579000.	0.	0.	0.	0.	0.	0.	0.	0.	0.
ANNUAL PLANT AND EQUIP.	0.	0.	0.	0.	0.	0.	2700000.	0.	0.	0.

PARAMETRIC PERCENTAGES:

PARAMETER	IDENTIFIER	VALUE	PARAMETER	IDENTIFIER	VALUE
INTEREST RATE	P11	10.00	UNITS MANUFACTURED PCT.	P21	120.00
AVERAGE INVENTORY PCT.	P23	20.00	ENGINEERING EXPENSE PCT.	P26	5.00
SELLING EXPENSE PCT.	P27	5.00	ADMINISTRATION EXPENSE PCT	P28	10.00
RECEIVABLES PCT.	P31	20.00	DEPRECIATION PERIOD(YRS)	P35	10.00
OTHER INVESTMENT PCT.	P38	5.00			

PERCENTAGE OF BASELINE USED INPUTS	IDENTIFIER	PCT	ADD/SUB FROM BASELINE INPUTS IDENTIFIER	VALUE
TOTAL MARKET	X1	100	A1	0.
MARKET SHARE	X2	100	A2	0.
UNIT PRICE	X3	100	A3	.00
UNIT MANUFACTURING COST	X4	100	A4	0.
R AND D EXPENSE	X5	100	A5	0.
ANNUAL PLANT AND EQUIP.	X6	100	A6	0.

Figure IV-1. Transparent Oxides Case A Input Values

	75	76	77	78	79	80	81	82	83	84
TOTAL MARKET (UNITS)	0.	0.	0.	0.	0.	0.	0.	15000.	15000.	15000.
MARKET SHARE (PCT)	.00	.00	.00	.00	.00	.00	.00	3.30	10.00	33.30
UNITS SOLD (UNITS)	0.	0.	0.	0.	0.	0.	0.	495.	1500.	4995.
UNIT PRICE	0.	0.	0.	0.	0.	0.	0.	830.	830.	830.
SALES	0.	0.	0.	0.	0.	0.	0.	410850.	1245000.	4145850.
OPERATING EXPENSES	504000.	2086000.	1690000.	634000.	727000.	1102000.	3268000.	2956311.	3071820.	4920771.
GROSS PROFITS	-504000.	-2086000.	-1690000.	-634000.	-727000.	-1102000.	-3268000.	-2545461.	-1826820.	-774921.
ANNUAL INVESTMENT	0.	0.	0.	0.	0.	0.	1980000.	1863326.	2303110.	2762656.
CUMULATIVE GROSS PROFITS	-504000.	-2590000.	-4280000.	-4914000.	-5641000.	-6743000.	10011000.	12556461.	14383281.	15158201.
BASE FOR INTEREST EXP.	504000.	2590000.	4280000.	4914000.	5641000.	6743000.	11991000.	14419787.	16686391.	17920857.
INTEREST EXPENSE	50400.	259000.	428000.	491400.	564100.	674300.	1199100.	1441979.	1668639.	1792086.
INCOME BEFORE TAXES	-554400.	-2345000.	-2118000.	-1125400.	-1291100.	-1776300.	-4467100.	-3987439.	-3495459.	-2567006.
TAXES	-266112.	-1125600.	-1016640.	-540192.	-619728.	-852624.	-2144208.	-1913971.	-1677820.	-1232163.
NET INCOME AFTER TAXES	-288288.	-1219400.	-1101360.	-585208.	-671372.	-923676.	-2322892.	-2073468.	-1817639.	-1334843.
NET CHANGE IN INVEST.	0.	0.	0.	0.	0.	0.	1980000.	-116674.	439784.	459546.
ANNUAL CASH FLOW	-288288.	-1219400.	-1101360.	-585208.	-671372.	-923676.	-4302892.	-1956795.	-2257422.	-1794390.
CUMULATIVE CASH FLOW	-288288.	-1507688.	-2609048.	-3194256.	-3865628.	-4789304.	-9092196.	-11048991.	-13306413.	-15100803.
RETURN ON INVESTMENT(PCT)	.00	.00	.00	.00	.00	.00	-117.32	-111.28	-78.92	-48.32
NET INCOME TO SALES (PCT)	.00	.00	.00	.00	.00	.00	.00	-504.68	-146.00	-32.20

O P E R A T I N G   E X P E N S E

	75	76	77	78	79	80	81	82	83	84
UNIT MANUFACTURING COST	.00	.00	.00	.00	.00	.00	.00	351.00	351.00	351.00
UNITS MANUFACTURED(UNITS)	0.	0.	0.	0.	0.	0.	0.	594.	1800.	5994.
COST OF GOODS MFG.	0.	0.	0.	0.	0.	0.	0.	208494.	631800.	2103894.
AVERAGE INVENTORY***	0.	0.	0.	0.	0.	0.	0.	41699.	126360.	420779.
R AND D EXPENSE	504000.	2086000.	1690000.	634000.	727000.	1102000.	3048000.	2476000.	2013000.	2024000.
ENGINEERING EXPENSE	0.	0.	0.	0.	0.	0.	0.	10425.	31590.	105195.
SELLING EXPENSE	0.	0.	0.	0.	0.	0.	0.	20542.	62250.	207292.
ADMINISTRATION EXPENSES	0.	0.	0.	0.	0.	0.	0.	20849.	63180.	210389.
DEPRECIATION EXPENSES**	0.	0.	0.	0.	0.	0.	220000.	220000.	270000.	270000.
TOTAL OPERATING EXPENSES	504000.	2086000.	1690000.	634000.	727000.	1102000.	3268000.	2956311.	3071820.	4920771.

I N V E S T M E N T

	75	76	77	78	79	80	81	82	83	84
RECEIVABLES (AVG)	0.	0.	0.	0.	0.	0.	0.	82170.	249000.	829170.
INVENTORIES (AVG)	0.	0.	0.	0.	0.	0.	0.	41699.	126360.	420779.
ANNUAL PLANT AND EQUIP.	0.	0.	0.	0.	0.	0.	2200000.	0.	500000.	0.
CUMULATIVE PLANT + EQUIP.	0.	0.	0.	0.	0.	0.	2200000.	2200000.	2700000.	2700000.
ANNUAL DEPRECIATION	0.	0.	0.	0.	0.	0.	220000.	220000.	270000.	270000.
CUMULATIVE DEPRECIATION	0.	0.	0.	0.	0.	0.	220000.	440000.	710000.	980000.
NET PLANT + EQUIP.	0.	0.	0.	0.	0.	0.	1980000.	1760000.	1990000.	1720000.
OTHER INVESTMENT****	0.	0.	0.	0.	0.	0.	0.	20542.	62250.	207292.
NET ANNUAL INVESTMENT	0.	0.	0.	0.	0.	0.	1980000.	1863326.	2303110.	2762656.
PRESENT VALUE OF ANNUAL CASH FLOW		-842875.								

* ASSUME TAX LOSS IS CREDITED AGAINST OTHER BUSINESS INCOME.
** THIS ITEM IS NORMALLY INCLUDED IN VARIOUS OVERHEAD ACCOUNTS.
*** INVENTORY DERIVATION IS HIGHLY SIMPLIFIED, BUT APPROXIMATES MORE COMPLEX METHODS
**** INCLUDES MISC. LIABILITIES SUCH AS ACCOUNTS PAYABLE, RESERVES, SUNDRY CREDITOR ITEMS

Figure IV-2A. Transparent Oxides Case A Cash Flow Analysis

	85	86	87	88	89	90	91	92	93	94
TOTAL MARKET (UNITS)	15000.	15000.	15000.	15000.	15000.	15000.	15000.	15000.	0.	0.
MARKET SHARE (PCT)	33.30	33.30	33.30	33.30	33.30	33.30	33.30	33.30	.00	.00
UNITS SOLD (UNITS)	4995.	4995.	4995.	4995.	4995.	4995.	4995.	4995.	0.	0.
UNIT PRICE	830.	830.	830.	830.	830.	830.	830.	830.	0.	0.
SALES	4145850.	4145850.	4145850.	4145850.	4145850.	4145850.	4145850.	4145850.	0.	0.
OPERATING EXPENSES	4475771.	2896771.	2896771.	2896771.	2896771.	2896771.	2946771.	2946771.	0.	0.
GROSS PROFITS	-329921.	1249079.	1249079.	1249079.	1249079.	1249079.	1199079.	1199079.	0.	0.
ANNUAL INVESTMENT	2492656.	2222656.	1952656.	1682656.	1412656.	1142656.	3522656.	3202656.	0.	0.
CUMULATIVE GROSS PROFITS	15488122.	14239042.	12989963.	11740884.	10491804.	-9242725.	-8043645.	-6844566.	0.	0.
BASE FOR INTEREST EXP.	17980778.	16461699.	14942619.	13423540.	11904460.	10385381.	11566302.	10047222.	0.	0.
INTEREST EXPENSE	1798078.	1646170.	1494262.	1342354.	1190446.	1038538.	1156630.	1004722.	0.	0.
INCOME BEFORE TAXES	-2127998.	-397090.	-245183.	-93275.	58633.	210541.	42449.	194357.	0.	0.
TAXES	-1021439.	-190603.	-117688.	-44772.	28144.	101060.	20376.	93291.	0.	0.
NET INCOME AFTER TAXES	-1106559.	-206487.	-127495.	-48503.	30489.	109481.	22074.	101066.	0.	0.
NET CHANGE IN INVEST.	-270000.	-270000.	-270000.	-270000.	-270000.	-270000.	2380000.	-320000.	0.	0.
ANNUAL CASH FLOW	-636559.	63513.	142505.	221497.	300489.	379481.	-2357926.	421066.	0.	0.
CUMULATIVE CASH FLOW	-15937362.	-15873849.	-15731344.	-15509847.	-15209357.	-14829876.	-17187802.	-16766737.	0.	0.
RETURN ON INVESTMENT(PCT)	-44.39	-9.29	-6.53	-2.88	2.16	9.56	.63	3.16	.00	.00
NET INCOME TO SALES (PCT)	-26.69	-4.98	-3.08	-1.17	.74	2.64	.53	2.44	.00	.00

O P E R A T I N G   E X P E N S E

	85	86	87	88	89	90	91	92	93	94
UNIT MANUFACTURING COST	351.00	351.00	351.00	351.00	351.00	351.00	351.00	351.00	.00	.00
UNITS MANUFACTURED(UNITS)	5994.	5994.	5994.	5994.	5994.	5994.	5994.	5994.	0.	0.
COST OF GOODS MFG.	2103894.	2103894.	2103894.	2103894.	2103894.	2103894.	2103894.	2103894.	0.	0.
AVERAGE INVENTORY***	420779.	420779.	420779.	420779.	420779.	420779.	420779.	420779.	0.	0.
R AND D EXPENSE	1579000.	0.	0.	0.	0.	0.	0.	0.	0.	0.
ENGINEERING EXPENSE	105195.	105195.	105195.	105195.	105195.	105195.	105195.	105195.	0.	0.
SELLING EXPENSE	207292.	207292.	207292.	207292.	207292.	207292.	207292.	207292.	0.	0.
ADMINISTRATION EXPENSES	210389.	210389.	210389.	210389.	210389.	210389.	210389.	210389.	0.	0.
DEPRECIATION EXPENSES**	270000.	270000.	270000.	270000.	270000.	270000.	320000.	320000.	0.	0.
TOTAL OPERATING EXPENSES	4475771.	2896771.	2896771.	2896771.	2896771.	2896771.	2946771.	2946771.	0.	0.

I N V E S T M E N T

	85	86	87	88	89	90	91	92	93	94
RECEIVABLES (AVG)	829170.	829170.	829170.	829170.	829170.	829170.	829170.	829170.	0.	0.
INVENTORIES (AVG)	420779.	420779.	420779.	420779.	420779.	420779.	420779.	420779.	0.	0.
ANNUAL PLANT AND EQUIP.	0.	0.	0.	0.	0.	0.	2700000.	0.	0.	0.
CUMULATIVE PLANT + EQUIP.	2700000.	2700000.	2700000.	2700000.	2700000.	2700000.	5400000.	5400000.	0.	0.
ANNUAL DEPRECIATION	270000.	270000.	270000.	270000.	270000.	270000.	320000.	320000.	0.	0.
CUMULATIVE DEPRECIATION	1250000.	1520000.	1790000.	2060000.	2330000.	2600000.	2920000.	3240000.	0.	0.
NET PLANT + EQUIP.	1450000.	1180000.	910000.	640000.	370000.	100000.	2480000.	2160000.	0.	0.
OTHER INVESTMENT****	207292.	207292.	207292.	207292.	207292.	207292.	207292.	207292.	0.	0.
NET ANNUAL INVESTMENT	2492656.	2222656.	1952656.	1682656.	1412656.	1142656.	3522656.	3202656.	0.	0.

PRESENT VALUE OF ANNUAL CASH FLOW -8842875.

* ASSUME TAX LOSS IS CREDITED AGAINST OTHER BUSINESS INCOME.
** THIS ITEM IS NORMALLY INCLUDED IN VARIOUS OVERHEAD ACCOUNTS.
*** INVENTORY DERIVATION IS HIGHLY SIMPLIFIED, BUT APPROXIMATES MORE COMPLEX METHODS
**** INCLUDES MISC. LIABILITIES SUCH AS ACCOUNTS PAYABLE, RESERVES, SUNDRY CREDITOR ITEMS

Figure IV-2B. Transparent Oxides Case A Cash Flow Analysis

INPUTS:	75	76	77	78	79	80	81	82	83	84
TOTAL MARKET (UNITS)	0.	0.	0.	0.	0.	0.	0.	15000.	15000.	15000.
MARKET SHARE (PCT)	0.	0.	0.	0.	0.	0.	0.	3.	10.	33.
UNIT PRICE	0.	0.	0.	0.	0.	0.	0.	830.	830.	830.
UNIT MANUFACTURING COST	.00	.00	.00	.00	.00	.00	.00	351.00	351.00	351.00
R AND D EXPENSE	0.	0.	0.	0.	727000.	797000.	1496000.	1539000.	1191000.	2003000.
ANNUAL PLANT AND EQUIP.	0.	0.	0.	0.	0.	0.	2200000.	0.	500000.	0.

INPUTS:	85	86	87	88	89	90	91	92	93	94
TOTAL MARKET (UNITS)	15000.	15000.	15000.	15000.	15000.	15000.	15000.	15000.	0.	0.
MARKET SHARE (PCT)	33.	33.	33.	33.	33.	33.	33.	33.	0.	0.
UNIT PRICE	830.	830.	830.	830.	830.	830.	830.	830.	0.	0.
UNIT MANUFACTURING COST	351.00	351.00	351.00	351.00	351.00	351.00	351.00	351.00	.00	.00
R AND D EXPENSE	1579000.	0.	0.	0.	0.	0.	0.	0.	0.	0.
ANNUAL PLANT AND EQUIP.	0.	0.	0.	0.	0.	0.	2700000.	0.	0.	0.

PARAMETRIC PERCENTAGES:

PARAMETER	IDENTIFIER	VALUE	PARAMETER	IDENTIFIER	VALUE
INTEREST RATE	P11	10.00	UNITS MANUFACTURED PCT.	P21	120.00
AVERAGE INVENTORY PCT.	P23	20.00	ENGINEERING EXPENSE PCT.	P26	5.00
SELLING EXPENSE PCT.	P27	5.00	ADMINISTRATION EXPENSE PCT	P28	10.00
RECEIVABLES PCT.	P31	20.00	DEPRECIATION PERIOD(YRS)	P35	10.00
OTHER INVESTMENT PCT.	P33	5.00			

PERCENTAGE OF BASELINE USED INPUTS	IDENTIFIER	PCT	ADD/SUB FROM BASELINE INPUTS IDENTIFIER	VALUE
TOTAL MARKET	X1	100	A1	0.
MARKET SHARE	X2	100	A2	0.
UNIT PRICE	X3	100	A3	.00
UNIT MANUFACTURING COST	X4	100	A4	0.
R AND D EXPENSE	X5	100	A5	0.
ANNUAL PLANT AND EQUIP.	X6	100	A6	0.

Figure IV-3. Transparent Oxides Case B Input Values

	75	76	77	78	79	80	81	82	83	84
TOTAL MARKET (UNITS)	0.	0.	0.	0.	0.	0.	0.	15000.	15000.	15000.
MARKET SHARE (PCT)	.00	.00	.00	.00	.00	.00	.00	3.30	10.00	33.30
UNITS SOLD (UNITS)	0.	0.	0.	0.	0.	0.	0.	495.	1500.	4995.
UNIT PRICE	0.	0.	0.	0.	0.	0.	0.	830.	830.	830.
SALES	0.	0.	0.	0.	0.	0.	0.	410850.	1245000.	4145850.
OPERATING EXPENSES	0.	0.	0.	0.	727000.	797000.	1716000.	2019311.	2249820.	4899771.
GROSS PROFITS	0.	0.	0.	0.	-727000.	-797000.	-1716000.	-1608461.	-1004820.	-753921.
ANNUAL INVESTMENT	0.	0.	0.	0.	0.	0.	1980000.	1863326.	2303110.	2762656.
CUMULATIVE GROSS PROFITS	0.	0.	0.	0.	-727000.	-1524000.	-3240000.	-4848461.	-5853281.	-6607201.
BASE FOR INTEREST EXP.	0.	0.	0.	0.	727000.	1524000.	5220000.	6711787.	8156391.	9369857.
INTEREST EXPENSE	0.	0.	0.	0.	72700.	152400.	522000.	671179.	815639.	936986.
INCOME BEFORE TAXES	0.	0.	0.	0.	-799700.	-949400.	-2238000.	-2279639.	-1820459.	-1690906.
TAXES	0.	0.	0.	0.	-383856.	-455712.	-1074240.	-1094227.	-873820.	-811636.
NET INCOME AFTER TAXES	0.	0.	0.	0.	-415844.	-493688.	-1163760.	-1185412.	-946639.	-879271.
NET CHANGE IN INVEST.	0.	0.	0.	0.	0.	0.	1980000.	-116674.	439784.	459546.
ANNUAL CASH FLOW	0.	0.	0.	0.	-415844.	-493688.	-3143760.	-1068739.	-1386422.	-1338818.
CUMULATIVE CASH FLOW	0.	0.	0.	0.	-415844.	-909532.	-4053292.	-5122031.	-6508453.	-7847271.
RETURN ON INVESTMENT(PCT)	.00	.00	.00	.00	.00	.00	-58.78	-63.62	-41.10	-31.83
NET INCOME TO SALES (PCT)	.00	.00	.00	.00	.00	.00	.00	-288.53	-76.04	-21.21

O P E R A T I N G E X P E N S E

	75	76	77	78	79	80	81	82	83	84
UNIT MANUFACTURING COST	.00	.00	.00	.00	.00	.00	.00	351.00	351.00	351.00
UNITS MANUFACTURED(UNITS)	0.	0.	0.	0.	0.	0.	0.	594.	1800.	5994.
COST OF GOODS MFG.	0.	0.	0.	0.	0.	0.	0.	208494.	631800.	2103894.
AVERAGE INVENTORY***	0.	0.	0.	0.	0.	0.	0.	41699.	126360.	420779.
R AND D EXPENSE	0.	0.	0.	0.	727000.	797000.	1496000.	1539000.	1191000.	2003000.
ENGINEERING EXPENSE	0.	0.	0.	0.	0.	0.	0.	10425.	31590.	105195.
SELLING EXPENSE	0.	0.	0.	0.	0.	0.	0.	20542.	62250.	207292.
ADMINISTRATION EXPENSES	0.	0.	0.	0.	0.	0.	0.	20849.	63180.	210389.
DEPRECIATION EXPENSES**	0.	0.	0.	0.	0.	0.	220000.	220000.	270000.	270000.
TOTAL OPERATING EXPENSES	0.	0.	0.	0.	727000.	797000.	1716000.	2019311.	2249820.	4899771.

I N V E S T M E N T

	75	76	77	78	79	80	81	82	83	84
RECEIVABLES (AVG)	0.	0.	0.	0.	0.	0.	0.	82170.	249000.	829170.
INVENTORIES (AVG)	0.	0.	0.	0.	0.	0.	0.	41699.	126360.	420779.
ANNUAL PLANT AND EQUIP.	0.	0.	0.	0.	0.	0.	2200000.	0.	500000.	0.
CUMULATIVE PLANT + EQUIP.	0.	0.	0.	0.	0.	0.	2200000.	2200000.	2700000.	2700000.
ANNUAL DEPRECIATION	0.	0.	0.	0.	0.	0.	220000.	220000.	270000.	270000.
CUMULATIVE DEPRECIATION	0.	0.	0.	0.	0.	0.	220000.	440000.	710000.	980000.
NET PLANT + EQUIP.	0.	0.	0.	0.	0.	0.	1980000.	1760000.	1990000.	1720000.
OTHER INVESTMENT****	0.	0.	0.	0.	0.	0.	0.	20542.	62250.	207292.
NET ANNUAL INVESTMENT	0.	0.	0.	0.	0.	0.	1980000.	1863326.	2303110.	2762656.
PRESENT VALUE OF ANNUAL CASH FLOW		-2939047.								

* ASSUME TAX LOSS IS CREDITED AGAINST OTHER BUSINESS INCOME.
** THIS ITEM IS NORMALLY INCLUDED IN VARIOUS OVERHEAD ACCOUNTS.
*** INVENTORY DERIVATION IS HIGHLY SIMPLIFIED, BUT APPROXIMATES MORE COMPLEX METHODS
**** INCLUDES MISC. LIABILITIES SUCH AS ACCOUNTS PAYABLE, RESERVES, SUNDRY CREDITOR ITEMS

Figure IV-4A. Transparent Oxides Case B Cash Flow Analysis

	85	86	87	88	89	90	91	92	93	94
TOTAL MARKET (UNITS)	15000.	15000.	15000.	15000.	15000.	15000.	15000.	15000.	0.	0.
MARKET SHARE (PCT)	33.30	33.30	33.30	33.30	33.30	33.30	33.30	33.30	.00	.00
UNITS SOLD (UNITS)	4995.	4995.	4995.	4995.	4995.	4995.	4995.	4995.	0.	0.
UNIT PRICE	830.	830.	830.	830.	830.	830.	830.	830.	0.	0.
SALES	4145850.	4145850.	4145850.	4145850.	4145850.	4145850.	4145850.	4145850.	0.	0.
OPERATING EXPENSES	4475771.	2896771.	2896771.	2896771.	2896771.	2896771.	2946771.	2946771.	0.	0.
GROSS PROFITS	-329921.	1249079.	1249079.	1249079.	1249079.	1249079.	1199079.	1199079.	0.	0.
ANNUAL INVESTMENT	2492656.	2222656.	1952656.	1682656.	1412656.	1142656.	3522656.	3202656.	0.	0.
CUMULATIVE GROSS PROFITS	-6937122.	-5688042.	-4438963.	-3189884.	-1940804.	-691725.	507355.	1706434.	0.	0.
BASE FOR INTEREST EXP.	9429778.	7910699.	6391619.	4872540.	3353460.	1834381.	3015302.	1496222.	0.	0.
INTEREST EXPENSE	942978.	791070.	639162.	487254.	335346.	183438.	301530.	149622.	0.	0.
INCOME BEFORE TAXES	-1272898.	458010.	609917.	761825.	913733.	1065641.	897549.	1049457.	0.	0.
TAXES	-610991.	219845.	292760.	365676.	438592.	511508.	430824.	503739.	0.	0.
NET INCOME AFTER TAXES	-661907.	238165.	317157.	396149.	475141.	554133.	466726.	545718.	0.	0.
NET CHANGE IN INVEST.	-270000.	-270000.	-270000.	-270000.	-270000.	-270000.	2380000.	-320000.	0.	0.
ANNUAL CASH FLOW	-391907.	508165.	587157.	666149.	745141.	824133.	-1913274.	865718.	0.	0.
CUMULATIVE CASH FLOW	-8239178.	-7731013.	-7143856.	-6477707.	-5732565.	-4908432.	-6821706.	-5955989.	0.	0.
RETURN ON INVESTMENT(PCT)	-26.55	10.72	16.24	23.54	33.63	48.50	13.25	17.04	.00	.00
NET INCOME TO SALES (PCT)	-15.97	5.74	7.65	9.56	11.46	13.37	11.26	13.16	.00	.00

O P E R A T I N G   E X P E N S E

	85	86	87	88	89	90	91	92	93	94
UNIT MANUFACTURING COST	351.00	351.00	351.00	351.00	351.00	351.00	351.00	351.00	.00	.00
UNITS MANUFACTURED(UNITS)	5994.	5994.	5994.	5994.	5994.	5994.	5994.	5994.	0.	0.
COST OF GOODS MFG.	2103894.	2103894.	2103894.	2103894.	2103894.	2103894.	2103894.	2103894.	0.	0.
AVERAGE INVENTORY***	420779.	420779.	420779.	420779.	420779.	420779.	420779.	420779.	0.	0.
R AND D EXPENSE	1579000.	0.	0.	0.	0.	0.	0.	0.	0.	0.
ENGINEERING EXPENSE	105195.	105195.	105195.	105195.	105195.	105195.	105195.	105195.	0.	0.
SELLING EXPENSE	207292.	207292.	207292.	207292.	207292.	207292.	207292.	207292.	0.	0.
ADMINISTRATION EXPENSES	210389.	210389.	210389.	210389.	210389.	210389.	210389.	210389.	0.	0.
DEPRECIATION EXPENSES**	270000.	270000.	270000.	270000.	270000.	270000.	320000.	320000.	0.	0.
TOTAL OPERATING EXPENSES	4475771.	2896771.	2896771.	2896771.	2896771.	2896771.	2946771.	2946771.	0.	0.

I N V E S T M E N T

	85	86	87	88	89	90	91	92	93	94
RECEIVABLES (AVG)	829170.	829170.	829170.	829170.	829170.	829170.	829170.	829170.	0.	0.
INVENTORIES (AVG)	420779.	420779.	420779.	420779.	420779.	420779.	420779.	420779.	0.	0.
ANNUAL PLANT AND EQUIP.	0.	0.	0.	0.	0.	0.	2700000.	0.	0.	0.
CUMULATIVE PLANT + EQUIP.	2700000.	2700000.	2700000.	2700000.	2700000.	2700000.	5400000.	5400000.	0.	0.
ANNUAL DEPRECIATION	270000.	270000.	270000.	270000.	270000.	270000.	320000.	320000.	0.	0.
CUMULATIVE DEPRECIATION	1250000.	1520000.	1790000.	2060000.	2330000.	2600000.	2920000.	3240000.	0.	0.
NET PLANT + EQUIP.	1450000.	1180000.	910000.	640000.	370000.	100000.	2480000.	2160000.	0.	0.
OTHER INVESTMENT****	207292.	207292.	207292.	207292.	207292.	207292.	207292.	207292.	0.	0.
NET ANNUAL INVESTMENT	2492656.	2222656.	1952656.	1682656.	1412656.	1142656.	3522656.	3202656.	0.	0.

PRESENT VALUE OF ANNUAL CASH FLO. -2339047.

* ASSUME TAX LOSS IS CREDITED AGAINST OTHER BUSINESS INCOME.
** THIS ITEM IS NORMALLY INCLUDED IN VARIOUS OVERHEAD ACCOUNTS.
*** INVENTORY DERIVATION IS HIGHLY SIMPLIFIED, BUT APPROXIMATES MORE COMPLEX METHODS
**** INCLUDES MISC. LIABILITIES SUCH AS ACCOUNTS PAYABLE, RESERVES, SUNDRY CREDITOR ITEMS

Figure IV-4B. Transparent Oxides Case B Cash Flow Analysis

INPUTS:	75	76	77	78	79	80	81	82	83	84
TOTAL MARKET (UNITS)	0.	0.	0.	0.	0.	0.	0.	15000.	15000.	15000.
MARKET SHARE (PCT)	0.	0.	0.	0.	0.	0.	0.	5.	15.	50.
UNIT PRICE	0.	0.	0.	0.	0.	0.	0.	1245.	1245.	1245.
UNIT MANUFACTURING COST	.00	.00	.00	.00	.00	.00	.00	351.00	351.00	351.00
R AND D EXPENSE	0.	0.	0.	0.	727000.	797000.	1496000.	1539000.	1191000.	2003000.
ANNUAL PLANT AND EQUIP.	0.	0.	0.	0.	0.	0.	2200000.	0.	500000.	0.

INPUTS:	85	86	87	88	89	90	91	92	93	94
TOTAL MARKET (UNITS)	15000.	15000.	15000.	15000.	15000.	15000.	15000.	15000.	0.	0.
MARKET SHARE (PCT)	50.	50.	50.	50.	50.	50.	50.	50.	0.	0.
UNIT PRICE	1245.	1245.	1245.	1245.	1245.	1245.	1245.	1245.	0.	0.
UNIT MANUFACTURING COST	351.00	351.00	351.00	351.00	351.00	351.00	351.00	351.00	.00	.00
R AND D EXPENSE	1579000.	0.	0.	0.	0.	0.	0.	0.	0.	0.
ANNUAL PLANT AND EQUIP.	0.	0.	0.	0.	0.	0.	2700000.	0.	0.	0.

PARAMETRIC PERCENTAGES:

PARAMETER	IDENTIFIER	VALUE	PARAMETER	IDENTIFIER	VALUE
INTEREST RATE	P11	10.00	UNITS MANUFACTURED PCT.	P21	120.00
AVERAGE INVENTORY PCT.	P23	20.00	ENGINEERING EXPENSE PCT.	P26	5.00
SELLING EXPENSE PCT.	P27	5.00	ADMINISTRATION EXPENSE PCT	P28	10.00
RECEIVABLES PCT.	P31	20.00	DEPRECIATION PERIOD(YRS)	P35	10.00
OTHER INVESTMENT PCT.	P38	5.00			

PERCENTAGE OF BASELINE USED INPUTS	IDENTIFIER	PCT	ADD/SUB FROM BASELINE INPUTS IDENTIFIER	VALUE
TOTAL MARKET	X1	100	A1	0.
MARKET SHARE	X2	100	A2	0.
UNIT PRICE	X3	100	A3	.00
UNIT MANUFACTURING COST	X4	100	A4	0.
R AND D EXPENSE	X5	100	A5	0.
ANNUAL PLANT AND EQUIP.	X6	100	A6	0.

Figure IV-5. Transparent Oxides Case C Input Values

	75	76	77	78	79	80	81	82	83	84
TOTAL MARKET (UNITS)	0.	0.	0.	0.	0.	0.	0.	15000.	15000.	15000.
MARKET SHARE (PCT)	.00	.00	.00	.00	.00	.00	.00	5.00	15.00	50.00
UNITS SOLD (UNITS)	0.	0.	0.	0.	0.	0.	0.	750.	2250.	7500.
UNIT PRICE	0.	0.	0.	0.	0.	0.	0.	1245.	1245.	1245.
SALES	0.	0.	0.	0.	0.	0.	0.	933750.	2801250.	9337500.
OPERATING EXPENSES	0.	0.	0.	0.	727000.	797000.	1716000.	2168972.	2690917.	6372725.
GROSS PROFITS	0.	0.	0.	0.	-727000.	-797000.	-1716000.	-1235222.	110333.	2964775.
ANNUAL INVESTMENT	0.	0.	0.	0.	0.	0.	1980000.	1963242.	2599727.	3752425.
CUMULATIVE GROSS PROFITS	0.	0.	0.	0.	-727000.	-1524000.	-3240000.	-4475222.	-4364890.	-1400115.
BASE FOR INTEREST EXP.	0.	0.	0.	0.	727000.	1524000.	5220000.	6438465.	6964617.	5152540.
INTEREST EXPENSE	0.	0.	0.	0.	72700.	152400.	522000.	643846.	696462.	515254.
INCOME BEFORE TAXES	0.	0.	0.	0.	-799700.	-949400.	-2238000.	-1879069.	-586129.	2449521.
TAXES	0.	0.	0.	0.	-383856.	-455712.	-1074240.	-901953.	-281342.	1175770.
NET INCOME AFTER TAXES	0.	0.	0.	0.	-415844.	-493688.	-1163760.	-977116.	-304787.	1273751.
NET CHANGE IN INVEST.	0.	0.	0.	0.	0.	0.	1980000.	-16758.	636485.	1152697.
ANNUAL CASH FLOW	0.	0.	0.	0.	-415844.	-493688.	-3143760.	-960358.	-941272.	121053.
CUMULATIVE CASH FLOW	0.	0.	0.	0.	-415844.	-909532.	-4053292.	-5013650.	-5954923.	-5833869.
RETURN ON INVESTMENT(PCT)	.00	.00	.00	.00	.00	.00	-58.78	-49.77	-11.72	33.94
NET INCOME TO SALES (PCT)	.00	.00	.00	.00	.00	.00	.00	-104.64	-10.88	13.64

O P E R A T I N G E X P E N S E

	75	76	77	78	79	80	81	82	83	84
UNIT MANUFACTURING COST	.00	.00	.00	.00	.00	.00	.00	351.00	351.00	351.00
UNITS MANUFACTURED(UNITS)	0.	0.	0.	0.	0.	0.	0.	900.	2700.	9000.
COST OF GOODS MFG.	0.	0.	0.	0.	0.	0.	0.	315900.	947700.	3159000.
AVERAGE INVENTORY***	0.	0.	0.	0.	0.	0.	0.	63180.	189540.	631800.
R AND D EXPENSE	0.	0.	0.	0.	727000.	797000.	1496000.	1539000.	1191000.	2003000.
ENGINEERING EXPENSE	0.	0.	0.	0.	0.	0.	0.	15795.	47385.	157950.
SELLING EXPENSE	0.	0.	0.	0.	0.	0.	0.	46687.	140062.	466875.
ADMINISTRATION EXPENSES	0.	0.	0.	0.	0.	0.	0.	31590.	94770.	315900.
DEPRECIATION EXPENSES**	0.	0.	0.	0.	0.	0.	220000.	220000.	270000.	270000.
TOTAL OPERATING EXPENSES	0.	0.	0.	0.	727000.	797000.	1716000.	2168972.	2690917.	6372725.

I N V E S T M E N T

	75	76	77	78	79	80	81	82	83	84
RECEIVABLES (AVG)	0.	0.	0.	0.	0.	0.	0.	186750.	560250.	1867500.
INVENTORIES (AVG)	0.	0.	0.	0.	0.	0.	0.	63180.	189540.	631800.
ANNUAL PLANT AND EQUIP.	0.	0.	0.	0.	0.	0.	2200000.	0.	500000.	0.
CUMULATIVE PLANT + EQUIP.	0.	0.	0.	0.	0.	0.	2200000.	2200000.	2700000.	2700000.
ANNUAL DEPRECIATION	0.	0.	0.	0.	0.	0.	220000.	220000.	270000.	270000.
CUMULATIVE DEPRECIATION	0.	0.	0.	0.	0.	0.	220000.	440000.	710000.	980000.
NET PLANT + EQUIP.	0.	0.	0.	0.	0.	0.	1980000.	1760000.	1990000.	1720000.
OTHER INVESTMENT****	0.	0.	0.	0.	0.	0.	0.	46687.	140062.	466875.
NET ANNUAL INVESTMENT	0.	0.	0.	0.	0.	0.	1980000.	1963242.	2599727.	3752425.
PRESENT VALUE OF ANNUAL CASH FLOW		3115132.								

* ASSUME TAX LOSS IS CREDITED AGAINST OTHER BUSINESS INCOME.
** THIS ITEM IS NORMALLY INCLUDED IN VARIOUS OVERHEAD ACCOUNTS.
*** INVENTORY DERIVATION IS HIGHLY SIMPLIFIED, BUT APPROXIMATES MORE COMPLEX METHODS
**** INCLUDES MISC. LIABILITIES SUCH AS ACCOUNTS PAYABLE, RESERVES, SUNDRY CREDITOR ITEMS

Figure IV-6A. Transparent Oxides Case C Cash Flow Analysis

	85	86	87	88	89	90	91	92	93	94
TOTAL MARKET (UNITS)	15000.	15000.	15000.	15000.	15000.	15000.	15000.	15000.	0.	0.
MARKET SHARE (PCT)	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	.00	.00
UNITS SOLD (UNITS)	7500.	7500.	7500.	7500.	7500.	7500.	7500.	7500.	0.	0.
UNIT PRICE	1245.	1245.	1245.	1245.	1245.	1245.	1245.	1245.	0.	0.
SALES	9337500.	9337500.	9337500.	9337500.	9337500.	9337500.	9337500.	9337500.	0.	0.
OPERATING EXPENSES	5948725.	4369725.	4369725.	4369725.	4369725.	4369725.	4419725.	4419725.	0.	0.
GROSS PROFITS	3388775.	4967775.	4967775.	4967775.	4967775.	4967775.	4917775.	4917775.	0.	0.
ANNUAL INVESTMENT	3482425.	3212425.	2942425.	2672425.	2402425.	2132425.	4512425.	4192425.	0.	0.
CUMULATIVE GROSS PROFITS	1988660.	6956435.	11924210.	16891985.	21859760.	26827535.	31745310.	36663085.	0.	0.
BASE FOR INTEREST EXP.	1433745.	0.	0.	0.	0.	0.	0.	0.	0.	0.
INTEREST EXPENSE	149376.	0.	0.	0.	0.	0.	0.	0.	0.	0.
INCOME BEFORE TAXES	3239399.	4967775.	4967775.	4967775.	4967775.	4967775.	4917775.	4917775.	0.	0.
TAXES	1554911.	2384532.	2384532.	2384532.	2384532.	2384532.	2360532.	2360532.	0.	0.
NET INCOME AFTER TAXES	1684487.	2583243.	2583243.	2583243.	2583243.	2583243.	2557243.	2557243.	0.	0.
NET CHANGE IN INVEST.	-270000.	-270000.	-270000.	-270000.	-270000.	-270000.	2380000.	-320000.	0.	0.
ANNUAL CASH FLOW	1954487.	2853243.	2853243.	2853243.	2853243.	2853243.	177243.	2877243.	0.	0.
CUMULATIVE CASH FLOW	-3879382.	-1026139.	1827104.	4680347.	7533590.	10386833.	10564076.	13441319.	0.	0.
RETURN ON INVESTMENT(PCT)	48.37	65.41	87.79	96.66	107.53	121.14	56.67	61.00	.00	.00
NET INCOME TO SALES (PCT)	18.04	27.67	27.67	27.67	27.67	27.67	27.39	27.39	.00	.00

O P E R A T I N G   E X P E N S E

	85	86	87	88	89	90	91	92	93	94
UNIT MANUFACTURING COST	351.00	351.00	351.00	351.00	351.00	351.00	351.00	351.00	.00	.00
UNITS MANUFACTURED(UNITS)	9000.	9000.	9000.	9000.	9000.	9000.	9000.	9000.	0.	0.
COST OF GOODS MFG.	3159000.	3159000.	3159000.	3159000.	3159000.	3159000.	3159000.	3159000.	0.	0.
AVERAGE INVENTORY***	631800.	631800.	631800.	631800.	631800.	631800.	631800.	631800.	0.	0.
R AND D EXPENSE	1579000.	0.	0.	0.	0.	0.	0.	0.	0.	0.
ENGINEERING EXPENSE	157950.	157950.	157950.	157950.	157950.	157950.	157950.	157950.	0.	0.
SELLING EXPENSE	466875.	466875.	466875.	466875.	466875.	466875.	466875.	466875.	0.	0.
ADMINISTRATION EXPENSES	315900.	315900.	315900.	315900.	315900.	315900.	315900.	315900.	0.	0.
DEPRECIATION EXPENSES**	270000.	270000.	270000.	270000.	270000.	270000.	320000.	320000.	0.	0.
TOTAL OPERATING EXPENSES	5948725.	4369725.	4369725.	4369725.	4369725.	4369725.	4419725.	4419725.	0.	0.

I N V E S T M E N T

	85	86	87	88	89	90	91	92	93	94
RECEIVABLES (AVG)	1867500.	1867500.	1867500.	1867500.	1867500.	1867500.	1867500.	1867500.	0.	0.
INVENTORIES (AVG)	631800.	631800.	631800.	631800.	631800.	631800.	631800.	631800.	0.	0.
ANNUAL PLANT AND EQUIP.	0.	0.	0.	0.	0.	0.	2700000.	0.	0.	0.
CUMULATIVE PLANT + EQUIP.	2700000.	2700000.	2700000.	2700000.	2700000.	2700000.	5400000.	5400000.	0.	0.
ANNUAL DEPRECIATION	270000.	270000.	270000.	270000.	270000.	270000.	320000.	320000.	0.	0.
CUMULATIVE DEPRECIATION	1250000.	1520000.	1790000.	2060000.	2330000.	2600000.	2920000.	3240000.	0.	0.
NET PLANT + EQUIP.	1450000.	1180000.	910000.	640000.	370000.	100000.	2480000.	2160000.	0.	0.
OTHER INVESTMENT****	466875.	466875.	466875.	466875.	466875.	466875.	466875.	466875.	0.	0.
NET ANNUAL INVESTMENT	3482425.	3212425.	2942425.	2672425.	2402425.	2132425.	4512425.	4192425.	0.	0.
PRESENT VALUE OF ANNUAL CASH FLOW			4115132.							

* ASSUME TAX LOSS IS CREDITED AGAINST OTHER BUSINESS INCOME.
** THIS ITEM IS NORMALLY INCLUDED IN VARIOUS EXPENSE ACCOUNTS.
*** INVENTORY DERIVATION IS HIGHLY SIMPLIFIED AND APPROXIMATES MORE COMPLEX METHODS
**** INCLUDES OTHER LIABILITIES SUCH AS ACCOUNTS PAYABLE, RESERVES, SUNDRY CREDITOR ITEMS

Figure IV-6B. Transparent Oxides Case C Cash Flow Analysis

The high uncertainity involved in all of the estimates used for this venture means that there is a wide range of possibilities for all values assumed. And, as the Case A, B, and C results show, the overall assessment of the venture can swing from negative to positive as these assumptions are changed. Therefore, this analysis should be taken only as a frame work for further study of what factors to concentrate on in order to increase confidence in results to the point at which a businessman could make a decision.

Figure IV-7 plots the key financial measures for Transparent Oxides.

	CASE A	CASE B	CASE C
% NI/S (1992)	2.4%	13 2%	27 4%
% ROI (1992)	3 2%	17 0%	61%
PRESENT VALUE	–$9M	–$3M	+$3M
USER R&D COST	$18M	$9 3M	$9 3M
NASA R&D COST	–	$8 6M	$8.6M
UNIT PRICE	$830	$830	$1245
MARKET SHARE	33%	33%	50%
BREAKEVEN POINT	> 20 YES	> 20 YRS	9 YRS

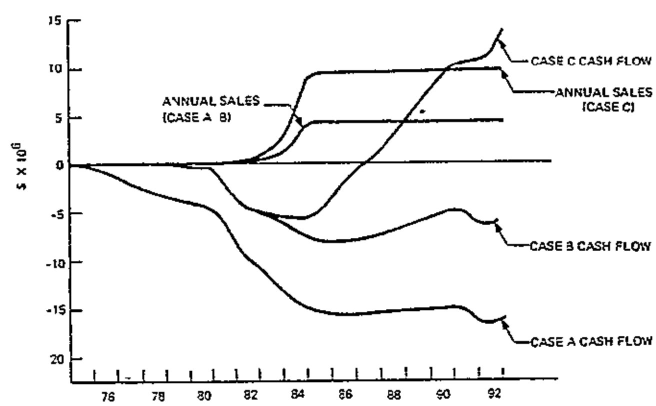


Figure IV-7. Transparent Oxides Cash Flow

SECTION V

MARKET ANALYSIS

V.1 INTRODUCTION

The market addressed is that for individual optical elements which would be installed in equipment operating in the infrared and ultraviolet portions of the spectrum. The elements would be formed of alumina, yttria, zirconia, etc. and would have a size, strength, and transparency superior to other available glasses. The selling price could thus be high enough to cover the costs of the space processing necessary to achieve those properties.

The concept for the business which would approach this market of interest is described in the following paragraphs.

V.1.1 ORGANIZATION

The business is established as a product line under a product manager in the house of an existing manufacturer of high quality optical goods, which has the support of an optical research laboratory. The roughly 5,000 finished optical elements which are produced each year are marketed (either as separate elements or as a part of higher level optical assemblies or equipments) via the existing sales and distribution channels of the manufacturer.

V.1.2 FACILITIES AND EQUIPMENT

The business obtains the transparent oxide raw materials and prepares the oxide charges for space charges in existing, modified facilities. Two space processing facilities (levitation and melt) are built, one for operations and one as back up. Each facility is capable of levitating and melting and supercooling oxide charges of nominally 8 cm diameter at a rate of up to 80 charge cycles per day (24 hours per day operation).

Annual production is 720 space-processed spheres, which are cut into about 5000 optical devices (Case A and B sales).

Production output is easily increased by increasing the number of days of facility operation in space. The oxide charges are transported to and from the space facility in a cartridge or magazine which provides for automated charge input and output from the levitation/melt facility. After return to the ground facility, the spheres are cut and polished into specific optical shapes to meet customer needs. Device sizes are limited by the initial charge diameter (8 cm).

V.1.3 INITIAL R&D

To reach production status, the business has incurred a significant expense in research and development of the space equipment and process required for oxide melt and amorphous solidification. This expense is in addition to government funding of programs to demonstrate basic process feasibility (Case B). This initial R&D expense is estimated (Cases B and C) at $9.3 million, spread over 7 years.

V.1.4 CONTINUING R&D (ENGINEERING DEVELOPMENT/ADVANCED ENGINEERING)

The business maintains a continuing R&D program for product improvement and facility development of 5% of sales, to assure a competitive product.

V.1.5 SPACE SHUTTLE SERVICES

Arrangements have been made with NASA for shuttle services for up-transport, on-orbit support, and down-transport of its oxide facility and charge magazines. On-orbit operating time is nominally 9 days, once per year, although success of the product could lead to greater space activity. The procedures for using shuttle services were established during the initial R&D phase, and service charges, legal considerations, schedules, etc. have been agreed to and documented.

V.1.6 INVENTORIES AND RECEIVABLES

The business produces relatively few product types in small quantities to order and limits its net inventory to 20% of sales. Receivables are assumed to be 20% of sales.

V.2 PRODUCT BENEFITS

The forms of alumina, zirconia, and yttria, as produced via containerless melting, are hoped to provide features which cannot be obtained in existing ground processes. Alumina glass, for example, may prove to be transparent to infrared wave lengths above 5 microns where silica glass becomes opaque. The high powered CO_2 lasers require infrared optics which possess high strength, high degree of perfection, and large size, all characteristics of the transparent oxides. The same characteristics would also apply to radiography and thermography. The range of potential benefits may become much broader when, and, if other materials (e.g. borides, nitrides, amorphous forms of metals, etc.) become amenable to the in-space containerless melting process. In this case, the market used in the cash flow analysis may prove to be very conservative.

V.3 COMPETITIVE PRODUCTS AND COMPETITORS

If the transparent oxide devices exhibit exceptionally low losses and are mechanically sturdy, they will be most attractive products. If, in addition, they could be made available in large diameters (8 to 10 cm or more), they would be still more attractive in the market place. Competing products would include the present day or improved germanium and gallium arsenide devices which sell at a significantly lower price. The oxide devices competitive features would be superior transparency, thermal, chemical and mechanical stability, with an acceptable premium price. Given a successful product, the competitor is another company who has developed a similar containerless process and obtained a shuttle service arrangement.

V.4 POTENTIAL ALTERNATIVES

The most serious alternative to the space-processed transparent oxide device, apart from the competing devices mentioned in paragraph V.3, would be the identical device manufactured on the ground. This would presume that ground based levitation and melt techniques in one gravity could achieve the same product quality and thus avoid incurring the space-processing expense. The capability for achieving this end in the terrestrial environment is presently unknown.

V.5 POTENTIAL BUYERS

The potential buyers of space-processed transparent oxide products include manufactures of optical components such as lenses and windows, who would buy the space produced boules. Buyers of components made from the boules include optical instrument makers, analytical instrument makers and the military. In the first category, Corning could be a logical buyer, while Itek and Perkin-Elmer could fit the other two categories.

V.6 MARKET FORECASTING

The market forecast is very rough due to the lack of a basis for estimating this demand. The product is a very high quality transparent oxide optical device of 20 cm^3 and undefined shape (as cut from an 8 cm diameter sphere) with applications in the infrared and far ultraviolet spectrum.

The sales of optical instruments and lenses in the U.S. in 1975 is projected at $800M, with an annual growth rate of 11%. (U.S. Industrial Outlook 1975, U.S. Dept. of Commerce.) Extending the 1975 forecast to 1983 gives a 1983 sales of $1843M. Assume that 10% of this total market is capturable by transparent oxides and that 20% of that fraction is applicable to high value infrared and far ultraviolet products, giving a market of ($1843M x .10 x .20) = $36.9 Million per year. For lack of a better basis, assume that the demand continues flat through 1992.

To determine the demand in terms of units, assume that one third of the annual sales ($36.9M) is attributable to the optical devices themselves (the remainder would be mounting and peripheral equipment). Assume that the average device sells for $830 (see Section V.7). Then the demand in units is [($36.9M x 1/3) ÷ $830] = 14,819, say 15,000 units per year for the period 1983 through 1992. Applying a build-up to this level from 1980 gives rough order of magnitude demand forecast as follows:

Year	Demand (Units)	Year	Demand (Units)
1980	1,000	1986	15,000
1981	5,000	1987	15,000
1982	10,000	1988	15,000
1983	15,000	1989	15,000
1984	15,000	1990	15,000
1985	15,000	1991	15,000
		1992	15,000

Figure V-1. U.S. Demand for Transparent Oxide Optical Devices 1980-1992

V.7 PRODUCT QUANTITIES/PRICING

Assuming that the unit price is attractive relative to device performance, a market share of 33.3% of the demand by 1984 is estimated, giving a sales forecast in units as follows: (This assumes significant outside competition).

Year	Sales (Units)	Year	Sales (Units)
1980	0	1986	5000
1981	0	1987	5000
1982	320	1988	5000
1983	1500	1989	5000
1984	5000	1990	5000
1985	5000	1991	5000
		1992	5000

Figure V-2. Transparent Oxide Sales

A unit price of \$830 has been set for analysis purposes, arrived at as follows. The present day value of germanium for infrared and for ultraviolet applications is estimated at \$12.50 per cm^3 (based on a blank of 1/4 inch thickness and 1-1/2 inch diameter selling for \$90). The value of gallium arsenide, which avoids the opacity problem of germanium when operated above $50^{\circ}C$, is estimated at \$34.72 per cm^3 (based on a blank of 7.2 cm^3 selling for \$250). Using the gallium arsenide as a more likely equivalent to the space processed oxides, plus a 20% value increase for the assumed superior performance of the space-processed oxide device, gives a value of \$34.72 x 1.2) = \$41.66 per cm^3 for the new device, and a baseline device of 20 cm^3 would be worth (\$41.66 x 20) = \$833.28, say \$830 per device.

V.8 PRODUCT LIFE CYCLE

The life cycle for transparent oxide optical devices is highly conjectural, since the process and the devices are conceptual at best. In the introduction phase, equipment manufacturers would be introduced to the product using R&D phase samples. Product decline would result from competition by a superior product alternative, presently unknown. Using an arbitrary 10 year maturity phase, the product life cycle would be about as follows:

Phase	From (Year)	To (Year)
Introduction	1980	1982
Growth	1983	1985
Maturity	1986	1995
Decline	1996	?
Exit	?	?

Figure V-3. Transparent Oxide Device Product Life Cycle

SECTION VI

COST/VALUE FOR PRODUCTION

This section presents the baseline production concept for producing Transparent Oxide optical devices, along with the assumptions and key findings for the product venture. It must be remembered that all figures given here are conceptual only, and are subject to change upon further and more detailed investigation.

VI.1 FLIGHTS AND RESOURCES REQUIRED FOR PILOT PLANT AND FULL SCALE PRODUCTION

The Transparent Oxide production process presents a series of ground-space process steps, with one in-space process step required, that of zero-G levitation, melting and re-solidification of the selected oxide. A throughput analysis, unit product cost breakdown, and rough breakdown of associated costs are provided in the following paragraphs.

VI.1.1 ANALYSIS OF PRODUCT VOLUME AND TIME VS. PAYLOAD CAPACITY AND TIME

The forecasted manufacturing volume is an initial output of about 500 units in 1982, growing to about 5000 units per year by 1984. The 1982 start implies the start of small-scale production while the R&D program (which ends in 1985) is still in process. The feasibility of this overlap would depend on assuming that experimental space facility designs were sufficient to produce the small initial quantities needed. The Transparent Oxide space processing facility envisioned would process up to 80 charges per day, which at 7 devices per charge, would produce up to 560 units per day. Thus, in the first year of production, a flight of one day would satisfy the annual requirement. At full-scale production of about 5000 units per year, one 9-day flight with one processing facility would suffice. Increased production could easily be accommodated by increasing flight time or number of facilities (processors). The levitation and melting facility would be a relatively heavy and bulky (but self-contained) unit, so that minimizing the number of facility launches would be desirable. A modular device (cartridge or magazine) for storing and feeding oxide charges into the levitation/melt chamber would be used to simplify handling of charges, and would also be used during up-transport and down-transport. The high energy consumption of the facility would probably be the item of greatest concern. A throughput analysis for the space and ground steps is shown in Figure VI-1, for an annual throughput of 5040 units.

VI.1.2 ANALYSIS OF PROCESSING SUPPORT REQUIREMENTS VS SHUTTLE/SPACELAB AVAILABLE RESOURCES

The space processing facility is conceived as being self-contained, except for special arrangements for input power and periodic crew attention. The facility would be initially launched with raw material input cartridges containing enough oxide charges for the mission duration and sufficient empty product output cartridges. Movement of charges from the input cartridge through the processing chamber and into the output cartridge would be completely automated, so that continuous operator attention would not be required. At the end of the production run, the output cartridge would be removed, for return to ground and another full cartridge would be installed. Shrinkage of the oxide charges during processing is estimated at 5% (95% yield) so that the output weight will be essentially the same as input weight.

An average of one man hour per day of crew time has been assumed, including cartridge installation and removal time. The input power requirement presents the most challenging aspect of in-orbit support for the transparent oxide facility. At an energy consumption level of 12 KWH per charge, and 720 charges per 9-day mission, 8640 KWH are required, and a peak input of 20-60 KW. The study has assumed that the space support agency will make such a power source available at a cost of $40 per KWH. This action appears feasible, but whether it will be done in the time frame 1982-1992 will determine the scale of production of transparent oxides and other energy-intensive products in that time period. An alternative approach, to use direct solar energy concentration, was not developed in the study, but could be a viable method.

1. Oxide Preparation Process

Number of oxide charges per year (7 devices per charge)	720
Charge diameter	8 cm
Charge weight	1340 grams
Charge volume	268 cm^3
Quantity of oxide required per year (720 x 1.34 kg)	965 kg

Oxide Preparation Facilities

Oxide Shaping Facility
Oxide Testing Facility

2. Oxide Space Process

No. of charges req'd per year	720
Charge size	8 cm diameter
Charge volume	268 cm^3
Charge density	5 gr/cm^3
Charge weight	1.34 kg
Process time per charge	18 minutes
No. of charges per day (1440 minutes - 18) (max.)	80
No. of days required per year (720 - 80)	9
No. of flights per year	1 (9 days)
Process yield factor	95% of weight
Process output (volume) (720 x 268 x .95)	183,312 cm^3
Process output (weight) (720 x 1.34 x .95)	917 kg
Process input (weight) (720 x 1.34)	965 kg
Energy required per flight (720 x 12 KWH)	8640 KWH (9-day mission)

Oxide Space Facilities

Space levitation/melt, cool facility
Charge storage unit (input and output)
Power conditioning/supply (up to 50 KW) ———

3. Oxide Finishing Process

Sphere size before cutting (weight)	7.72 cm diam.
Sphere size before cutting (volume)	241.2 cm^3
No. of spheres per year	720
Cutting yield factor	60%
Polishing yield factor	95%
Useful volume after cut & polish (per sphere) (241.2 x .60 x .95)	137.5 cm^3
Useful volume output per year (137.5 x 720)	99,000 cm^3
Useful weight output per year (99,000 cm^3 x 5 gr)	495 kg
Typical volume of optical device	20 cm^3
Typical no. of optical devices per sphere (137.5 - 20)	7
No. of optical devices output per year (720 x 7)	5040

Oxide Finishing Facilities

Oxide cutting & polishing facility (optical quality)
Optical item test & packaging facility

Figure VI-1. Transparent Oxides Throughput Analysis
Basis: 5040 devices per year

This approach would lead to a different facility concept than was used in this study, which assumed an electrical rather than heat energy input to the facility.

VI.1.3 DETERMINATION OF NUMBER OF FLIGHTS FOR PILOT PLANT AND PRODUCTION

A baseline assumption of one 9-day flight per year for space processing transparent oxides has been used, relative to an annual production requirement of about 5000 oxide devices. Lower level production in the early years would probably use a similar facility and flight arrangements (with reduced operating time), while an annual production higher than 5000 units would use either more flights or more facilities (processors) per flight, assuming that sufficient process energy were available.

The product and process concept and power source arrangements are such that these considerations are highly speculative at this time.

VI.1.4 DETERMINATION OF RESOURCES REQUIRED FOR PILOT PLANT AND PRODUCTION

A summary of the production resource requirements is shown in Figure VI-2. Plant and equipment requirements are roughly estimated as shown in Figure VI-3. Further data on production costs is given in Section IV, Cash Flow Analysis.

VI.2 ANALYSIS OF PRODUCT COSTS

A breakdown of the manufacturing costs by process step for an annual production level of 5040 units is shown in Figure IV-4. A unit manufacturing cost of $351 was used for all cases, all years of the financial forecast, (Section IV).

VI.2.1 SHUTTLE/SPACELAB OPERATION COSTS AND RESOURCE COSTS

Annual space operations costs at an annual production level of 5040 units are estimated at $1168K (Figure VI-5). Most of this amount ($1017K) is for shuttle service charges. The basis for the space service charges is shown in Figure VI-5.

Materials

Alumina, yttria, zirconia and other oxide rods or pressed and sintered charges (8 cm diam)

Services

Shuttle launch and support (NASA)
In-space power source (50 KW)

Equipment

Production scale positioning, levitation and melting apparatus (O-G)
Oxide charge preparation equipment
Oxide finishing (cut, polish, package) equipment

Facilities

Oxide charge preparation lab
Launch and Return facilities (Shuttle) (NASA)
Oxide finishing lab

Special Manpower Skills

Optical glasses specialists
Optical device specialists
Oxide levitation, position, melt process specialists

Figure VI-2. Transparent Oxides Production Resource Requirements Summary

Oxide Preparation	81	82	83	84	85	86	87	88	89	90	91
Oxide Shaping	400K	-	-	-	-	-	-	-	-	-	400K
Oxide Testing	300K	-	-	-	-	-	-	-	-	-	300K
Oxide Preparation											
Space Facility (2)*	500K	-	500K	-	-	-	-	-	-	-	1000K
Oxide Finishing											
Oxide Cut and Polish	600K	-	-	-	-	-	-	-	-	-	600K
Device Test and Package	400K	-	-	-	-	-	-	-	-	-	400K
Annual Totals	2200K	-	500K	-	-	-	-	-	-	-	2700K

*1 facility in orbit, 1 backup.

Figure VI-3. Transparent Oxides Plant and Equipment Estimates

Basis: 720 charges or 5040 devices/yr, 7 devices per charge.

	Annual Cost	Unit Cost (per device)
Oxide Preparation		
Preparation labor (720 x $50)	36K	
Oxide Materials (720 x 1.34 Kg x $220/kg)	212K	
Overhead (100% of labor)	36K	
Total	$284K	$ 56.34
Oxide Space Processing		
Ground Operations Labor	73K	
Materials (misc.)	5K	
Services, shuttle (NASA)	1017K	
Overhead (100% of labor)	73K	
Total	$ 1168K	$231.74
Oxide Finishing Process		
Device cut & polish labor (5040 x $20)	101K	
Test & package labor (5040 x $10)	50K	
Materials (misc) (5040 x $3)	15K	
Overhead (100% of labor)	151K	
Total	$ 317K	$ 62.89
Grand Total	$ 1769K	$350.97

Figure IV-4. Unit Manufacturing Cost Transparent Oxide Devices

Basis: 5040 devices = 720 charges & 1 flights/yr (approx. 9 days)

		Annual Charges
Up-transport Volume		
($3.0M^3$ @ $13760/$M^3$)	$	41K
($1.0M^3$ x 2 cartridges @ $13760/$M^3$)		28K
Up transport weight		
800 kg @ $110/kg) facility		88K
(720 charges @ 1.34 kg x $110 kg) materials		106K
On-orbit energy		
(720 charges @ 12KWH x $40/KWH)		346K
On-orbit crew		
(1 man hr/day x 9 days x $6450/hr)		58K
(2 cartridges x 2 hrs x $6450/hr)		26K
On-orbit data transmission		None
On-orbit data processing		None
Down transport weight		
(800 kg x $180/kg) facility		144K
(720 charges x 1.34 kg x $180/kg) materials		174K
Ground Ops (Volume)		
[($3.0M^3$ + 2.0M) x $1280/$M^3$]		6K
Ground Ops (complexity)		None
		$1017K

Figure VI-5. Calculation of Transparent Oxides Space Charges for Production

VI. 2. 2 DEFINITION OF ADDITIONAL NON-SPACE PROGRAM COSTS

The non-space processing steps, oxide preparation and oxide finishing (cut and polish), account for about 34% of the total process cost (Figure VI-4). All of the ground processing is assumed to be performed in existing plant space. The small production quantities do not require significant ground plant capacity.

VI. 2. 3 ANALYSIS OF TOTAL PRODUCTION COSTS

The Transparent Oxide device selling price is the key to establishing a significant demand for the product. The $830 unit price used for Cases A and B analysis appears to be as high a price as can be charged, unless extraordinary device features are demonstrated. Therefore the $351 unit manufacturing cost, with its high content of space processing costs, is a major area of concern if the business is to achieve an acceptable breakeven point. (See Section IV, Cash Flow Analysis.) Although all of the estimates used are speculative, specific attention should be given in future studies, to the means for reducing unit manufacturing cost, and attempting to lower the unit selling price.

VI. 3 ANALYSIS OF COST/VALUE

The Case B financial forecast for the Transparent Oxides (ref. Section IV, Cash Flow Analysis) presents an unattractive breakeven point and an unattractive present value, due to the burden of the R&D program. The space facility is under-utilized, due to the small market size, and the ultimate market size and market share will have an important effect on this venture. The estimates used may prove to have been overly conservative. Case C, with higher selling price and higher market share, is closest to being able to carry the R&D program costs.

VI. 3. 1 DERIVATION OF GROSS MARGIN

Gross margin, or the difference between unit manufacturing cost and selling price, for the Case B case, is estimated at $830-$351 = $479, 58% of selling price or 136%

of unit manufacturing cost. This relationship was used in all years of the Case A and Case B forecasts. Gross margin allows for net profit and expenses other than shop cost, as shown in Section IV.

VI.3.2 IDENTIFICATION OF SIGNIFICANT COST/VALUE ASSUMPTIONS

A key assumption in forecasting the business was that large amounts of power (in the range of 60 KW) could be made available in space at the relatively low cost of $40/KWH. The feasibility of the in-space, containerless melting process has been assumed. Also, it has been assumed that no ground alternative process will be developed in the same time frame, and that the amorphous and/or high transmissivity form of various transparent oxides and other materials will give superior performance in the infrared and ultraviolet portions of the spectrum.

The R&D program used, (Case B), assumes that NASA will fund sufficient experiments to demonstrate overall process feasibility. The R&D costs included, assume that all experiments are successful, and that only a few flights are required to achieve pilot production capability. The space service charges are based on the BUS Phase III model and are a significant cost factor in the financial forecast. Any changes in the basis for space charges will thus have a significant effect on the forecasted venture viability.

VI.3.3 SENSITIVITY ANALYSIS

The "present value" of the product venture (as explained in Section IV), discounted at 10% has been used as a common measure for assessing the sensitivity of the venture to the estimates used for the various cost elements. Each of the parameters used in the cash flow analysis was varied $\pm$ 10%, and the financial forecast was calculated for each case a total of 30 projections. The resultant present value in each case was then compared with the Case B present value, giving the delta low(-10%) and delta high (+10%) figures as shown in Figure VI-6.

INVEST - INTERACTIVE NEW VENTURE EXAMINATION AND SENSITIVITY TEST

SENSITIVITY ANALYSIS OF CHANGE IN PRESENT VALUE
FOR 10 PCT. CHANGE IN PARAMETER VALUE

ITEM	PARAMETER	DELTA LOW	DELTA HIGH
1	INTEREST RATE	144264.	-144264.
2	UNITS MANUFACTURED PCT.	534421.	-542858.
3	AVERAGE INVENTORY PCT.	16547.	-16547.
4	ENGINEERING EXPENSE PCT.	22883.	-22883.
5	SELLING EXPENSE PCT.	45092.	-45092.
6	ADMIN EXPENSE PCT.	45766.	-45766.
7	RECEIVABLES PCT.	32607.	-32607.
8	DEPRECIATION PERIOD(YRS)	13922.	-8804.
9	OTHER INVESTMENT PCT.	-8152.	8152.
10	TOTAL MARKET UNITS	-289444.	289444.
11	MARKET SHARE PCT.	-289444.	289444.
12	UNIT PRICE $	-832302.	794969.
13	UNIT MFG'D COST $	534421.	-542858.
14	R + D COST $	410624.	-410624.
15	ANNUAL PLANT + EQUIP $	172725.	-172725.

PRODUCT IS TRANSPARENT OXIDES CASE B
BASELINE PRESENT VALUE = -2939047.

Figure VI-6. Transparent Oxides Parameter Sensitivity Analysis

The parameters with the largest change in present value for a 10% change in estimate are thus of most interest. The high-sensitivity parameters are plotted in Figure VI-7.

Unit price, unit manufacturing cost (including space service charges) and R&D costs show high sensitivity, so that these cost estimates should receive close attention in further studies.

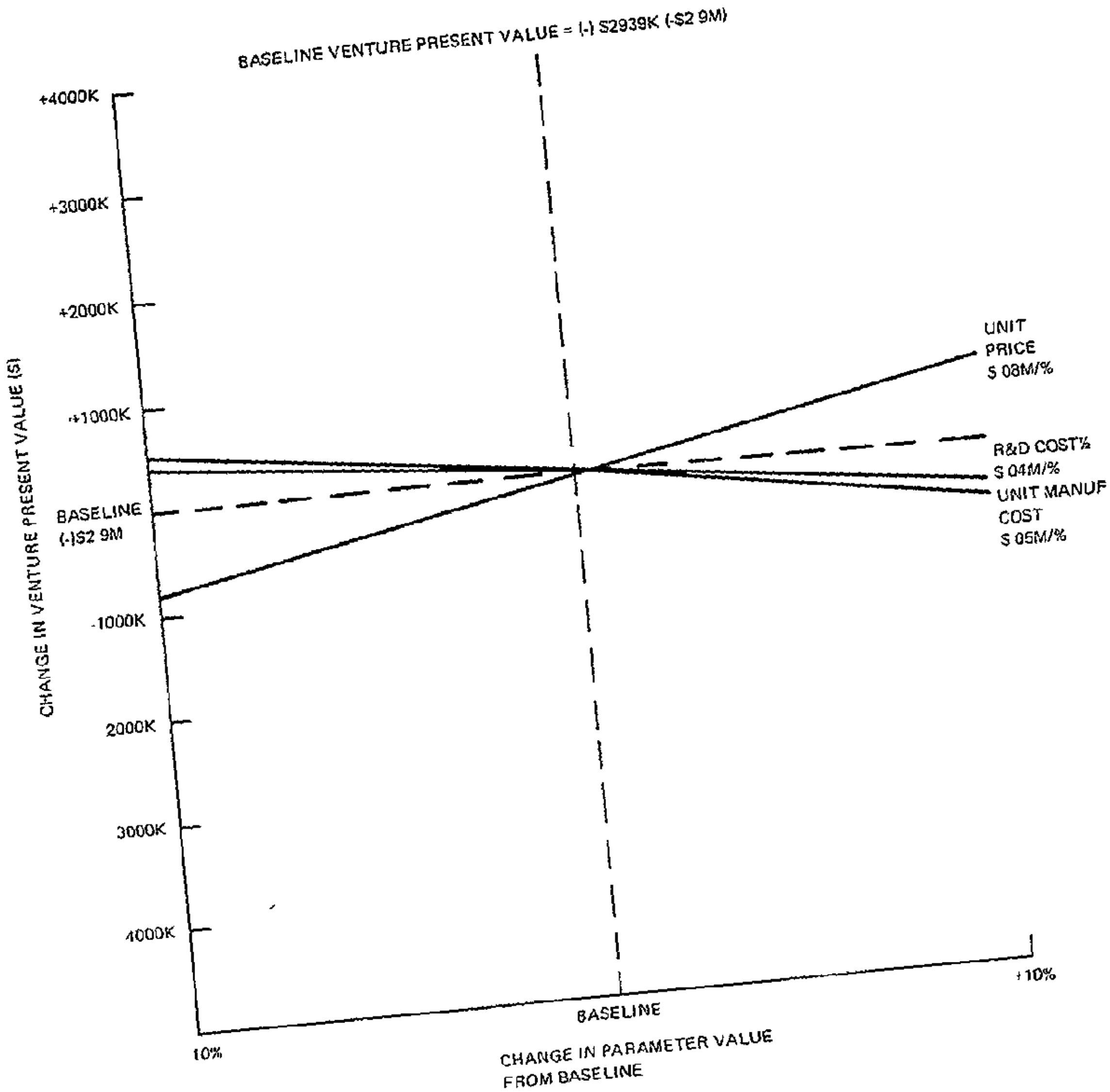


Figure VI-7. Transparent Oxides Parameter Sensitivity

GENERAL ELECTRIC

Space Division

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